Marine Fisheries REVIEW

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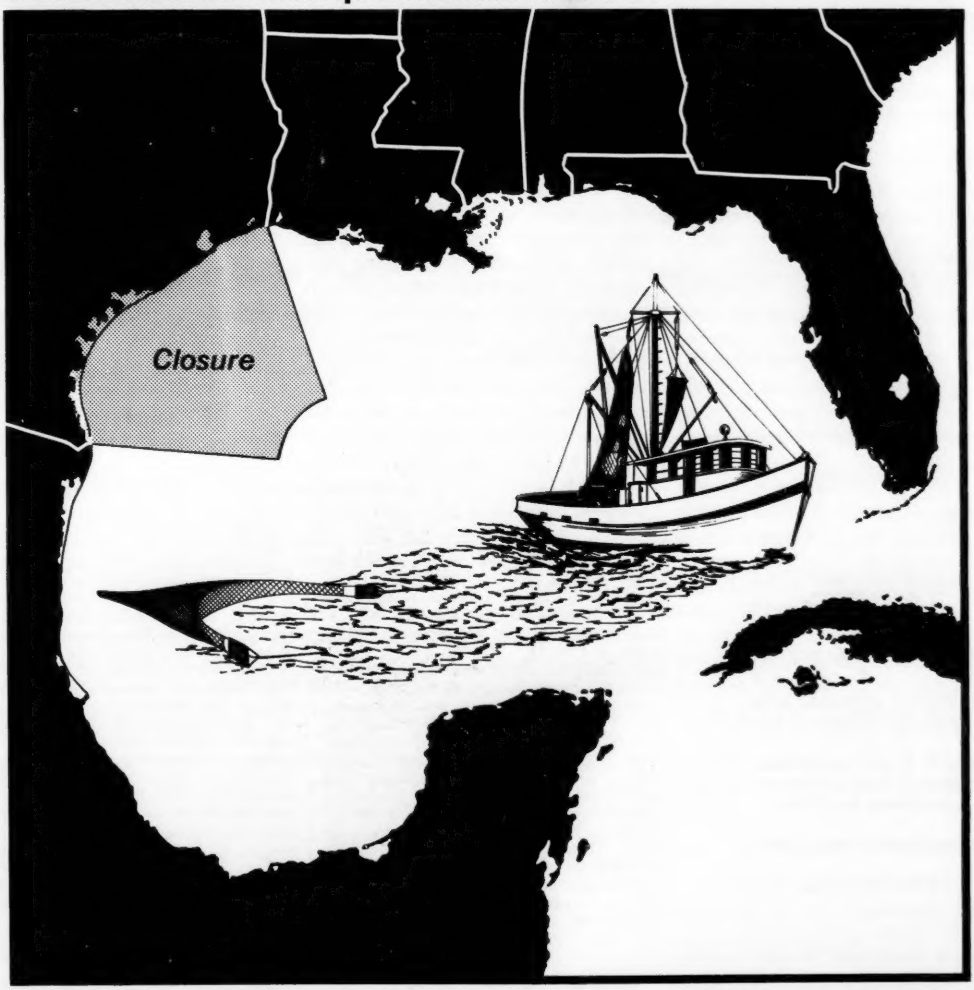
Gulf of Mexico Shrimp Fisheries and . . .



. . . the 1981 Texas Closure

Marine Fisheries REVIEW

On the cover: The Texas Closure area discussed in this issue.

Articles — *September-October, 44(9-10)*

Effects of the 1981 Closure on the Texas Shrimp Fishery	*Albert C. Jones, Edward F. Klima,* and *John R. Poffenberger*	1
Relative Abundance and Size Distributions of Commercially Important Shrimp During the 1981 Texas Closure	*Geoffrey A. Matthews*	5
A Review of the Offshore Shrimp Fishery and the 1981 Texas Closure	*Edward F. Klima, Kenneth N. Baxter,* and *Frank J. Patella, Jr.*	16
Impacts on Shrimp Yields of the 1981 Fishery Conservation Zone Closure off Texas	*Scott Nichols*	31
Estimated Impacts on Ex-Vessel Brown Shrimp Prices and Value as a Result of the Texas Closure Regulation	*John R. Poffenberger*	38
Comparison of Shrimp and Finfish Catch Rates and Ratios for Texas and Louisiana	*Noel H. Watts* and *Gilmore J. Pellegrin, Jr.*	44
Shrimp Fleet Mobility in Relation to the 1981 Texas Closure	*Albert C. Jones* and *James R. Zweifel*	50
Survey of Ice Plants in Louisiana, Mississippi, and Alabama, 1980-81	*John M. Ward* and *John R. Poffenberger*	55

Departments

NOAA/NMFS Developments	58
Foreign Fishery Developments	60
Publications	63

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Effects of the 1981 Closure on the Texas Shrimp Fishery

ALBERT C. JONES, EDWARD F. KLIMA, and JOHN R. POFFENBERGER

Introduction

Shrimp fisheries in the Fishery Conservation Zone (FCZ) in the Gulf of Mexico are federally managed by the Shrimp Fishery Management Plan, which was implemented by the Secretary of Commerce on 15 May 1981. A major regulation within this plan prohibits fishing for brown shrimp, *Penaeus aztecus*, in the FCZ off the coast of Texas during the time of year when large numbers of juvenile shrimp migrate from the bays and estuaries to offshore waters. The time of the closure corresponds with the closure by the State of Texas of its territorial sea. In 1981 the closure in the FCZ and Texas' territorial sea was from 22 May through 15 July.

The objective of the 1981 "Texas closure" regulation was to increase both the quantity and monetary value of brown shrimp harvested from the Texas coastal areas. It was anticipated that the closure of these areas when juvenile shrimp are migrating offshore would achieve this objective. The closure regulation was also expected to eliminate the discard of smaller, unmarketable shrimp by the fishermen because, simultaneous to the implementation of the plan, the State of Texas removed its law restricting landings of undersize shrimp. Before the implementation of the plan, the potential benefits of this closure regulation were estimated (NOAA, 1980). Nevertheless, considerable apprehension was expressed by some members of the fishing community that the regulation would be ineffective and would adversely affect shrimp fisheries in other Gulf States. Because of these concerns, the Southeast Fisheries Center was requested to monitor and evaluate the impacts of the regulation during the initial months after its implementation on 22 May 1981.

Research on various aspects of the Texas closure regulation was designed and conducted by scientists at the Southeast Fisheries Center and was composed of specific data collection and analytical efforts. Two fishery research vessels sampled shrimp populations in the closed area from May to July. Near-synoptic coverage of the Texas FCZ by these vessels provided an estimate of the magnitude and size composition of the shrimp population in the closed area. Additional coverage by one vessel in May and July provided information on temporal changes of the area's shrimp population. In addition, data on fishery activity (catch, effort, and location of fishing) were collected in each of the Gulf States (Texas to Florida) by interviewing dealers and selected fishermen. At-sea observers on shrimp vessels, in the course of other duties, collected data on magnitude and species composition of the incidental catch of fish both in the regulated area and in unregulated areas. Finally, daily sales data were collected from ice manufacturers in Louisiana, Mississippi, and Alabama as an estimate of shore facility use in these areas. Data from these field studies were processed, analyzed, and compared with available historical data. The results (as well as the research and analytical methodologies) were presented to the Gulf of Mexico Fishery Management Council in December 1981.

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This issue of the *Marine Fisheries Review* contains articles on the research done by the Southeast Fisheries Center on the effects of the Texas closure regulation. Our overview report synthesizes the scientific results from these articles and provides answers to technical questions relating to the management of this penaeid fishery. These questions, formulated in consultation with fishery administrators, were designed to provide scientific information upon which to base fishery management policies for the Gulf shrimp fisheries. The topics cover: 1) Size composition and abundance of shrimp in the area during the time it was closed to fishing; 2) quantity and value of brown shrimp harvested by the regulated fishery compared with amounts that would have been taken had the fishery not been regulated; 3) changes in fishing patterns and use of shore facilities that resulted from the closure regulation; and 4) other possible effects on the resource and fishery.

Abundance of Shrimp

A high abundance of brown shrimp in Texas in 1981 was documented by recruitment indices, results of trawl surveys made in the closed area, and statistical records on the fishery. Biologists annually measure abundance and survival of small shrimp in Texas bays

and estuaries; they reported that recruitment in these inshore areas was good in 1981. Brown shrimp recruitment was generally comparable with (but not better than) recruitment in the above-average shrimp production years of 1967, 1972, 1976, and 1977 (Klima et al., 1982). Only in one area of Texas, the lower Laguna Madre, was recruitment in 1981 substantially better than in the above-average years.

Evidence of good recruitment in Texas bays was accompanied by evidence of high shrimp abundance in the Texas offshore areas during June, July, and August 1981, as measured on the research cruises and by fishing records. Although historical data are somewhat limited, catch per unit of effort measured on research surveys in 1981 appeared to be greater than that measured in earlier years. The 1981 observations (Matthews, 1982) suggest that large biomasses of small shrimp were present along the entire Texas coast, with especially high concentrations of shrimp in the depth range of 10-20 fathoms (fm). Thus, shrimp were protected from fishing as a result of the closure. Fishing success off Texas was at record levels in July and August 1981. Offshore Texas catches were 10.3 million pounds from 16 to 31 July and 14.6 million pounds for August (Klima et al., 1982). Catch rates were 2,250 and 1,346 pounds per 24-hours fishing for July and August, respectively. These catches and catch rates were markedly higher than in any other year examined.

In Louisiana, abundances of brown shrimp were documented by recruitment indices and statistical records on the fishery. Brown shrimp recruitment in Louisiana in 1981 was reported to be at record levels[1]. Inshore recruitment occurred over an extended period, and survival during the spring recruitment phase was high because of favorable temperatures and salinities. These shrimp contributed to a reportedly successful fishery in the inside waters of Louisiana and after migration to a good fishery in offshore waters in June through August. Offshore catches were 7.5 million pounds in June, 7.4 million pounds in July, and 2.9 million pounds in August (Klima et al., 1982). However, these catches and the associated catch rates, unlike those reported in Texas waters, were not significantly higher than shrimp production in any other year.

Since the catches off the Texas coast were at record levels and recruitment did not appear to be significantly better than in above average years, other factors may have caused the record catches. For example, abundance of shrimp in Louisiana areas was high during the period of the closure regulation and it was suggested that migration from these areas may have supported the large abundance in the offshore Texas area. However, extensive data from marking studies previously conducted in Louisiana indicate that the majority of shrimp migrating offshore are captured in the immediate area (within about 60 miles of where they enter the ocean) and very few make longer migrations. Thus, while recruitment in Louisiana was very high in 1981 and the catch rates offshore of Louisiana were good, there is no evidence to indicate that these shrimp contributed to the fishery off Texas or other states.

In summary, although recruitment in both Texas and Louisiana waters was good in 1981, recruitment levels in neither area satisfactorily account for the highly successful July-August fishery off Texas. In particular, observed catches and catch rates offshore of Texas were markedly higher than would have been predicted from existing recruitment indices based on historical data.

Magnitude of Catch

In July and August, the offshore Texas fishery harvested approximately 875 million shrimp weighing 24.9 million pounds at average monthly catch rates of 2,250 and 1,346 pounds, respectively, per 24-hours fishing. In contrast, fishermen in the offshore Louisiana fishery from June through August harvested approximately the same number of shrimp (867 million) but weighing less (17.8 million pounds) and taken at lower catch rates of 687-858 pounds per 24-hours fishing. Moreover, as a consequence of the smaller size of shrimp caught in the offshore Louisiana fishery, the ex-vessel value of these shrimp was less than that of shrimp caught in the offshore Texas fishery. Of practical importance and analytical interest is the possible contribution of the regulation to the larger and more valuable catches in Texas waters. In other words, to what extent did the regulation enhance the yield and value obtained from the available recruitment? Two approaches to estimating yield provided information on this question.

First, a yield-per-recruit analysis was applied, using an estimated population age composition of 22 May (the start of the closure) as the measure of recruitment (Nichols, 1982). This population age composition was determined from measurements made on the research vessel survey of the FCZ off Texas in June, combined with estimates of growth and mortality. The simulation predicted that the standing stock of brown shrimp in the regulated area increased 78 percent in weight during the closed period, due to the gain in growth exceeding the loss from mortality. As a result, an enhancement of yield from closure of the Texas FCZ was predicted for most fishing mortality rates. The percentage gain in potential yield varied from less than zero at very small fishing mortality rates to more than 40 percent at higher rates.

Second, a virtual population analysis was applied, using catch and effort data for the Gulfwide, offshore brown shrimp fishery, which encompasses waters off Texas, Louisiana, Mississippi, Alabama, and eastern Florida. The observed catch in 1981 was compared with the predicted catch that would have been taken had the Texas FCZ not been closed. Results indicated that with the closure the May-August observed harvest of 52.8 million pounds was 11.7 million pounds (29 percent) higher than if there had been no closure. However, much of that increase

[1]White, Charles. Louisiana Department of Wildlife and Fisheries, 400 Royal Street, New Orleans, LA 70130, pers. commun.

in catch was realized at the expense of the standing stock. The biomass as of 1 August was reduced by 18 percent compared with the biomass estimated for an unregulated fishery. When the expected yield was compared over the fishable lifespan of the shrimp cohort (estimated as 2 years), the estimated harvest of 65.0 million pounds was 4.1 million pounds (7 percent) higher than if there had been no closure.

The two simulations of the effect of the regulation on harvest are in reasonable agreement. One method estimated the change in yield from the Texas FCZ only, whereas the other method estimated the change in yield from the Gulfwide fishery. Since the Texas FCZ contained about 29 percent of the Gulfwide brown shrimp population, and the likely increase in yield there from the closure was about 40 percent, the overall fishery gain of 12 percent estimated by the yield-per-recruit approach is close to the 7 percent gain estimated by the virtual population analysis.

Fundamental economic principles associated with the theory of supply and demand indicate that in unrestricted markets the price of a commodity can be expected to decrease if the supply of that commodity increases (assuming there is no change in demand). Therefore, since the regulation resulted in an (estimated) increase in the supply of domestically harvested brown shrimp, it is completely consistent with economic theory to expect a decrease in the ex-vessel price paid to the fishermen. The important analytical question is to estimate how much of the decrease in price can be explained based on historical changes in landings and the concomitant changes in ex-vessel prices.

The statistical relationship between changes in ex-vessel prices and changes in landings is termed "price flexibility." Since the estimation of price flexibilities is fundamental to estimating the effects on the ex-vessel value of the brown shrimp fishery, an analytical technique had to be used that estimated the relationship between price and landings while all the other influential factors were held constant. Price flexibilities were estimated by simple and multiple regression. The simple regression model estimated ex-vessel prices for the eight marketing or size categories of shrimp as a function of the amount of landings in the respective size categories. The hypothesis underlying this model specification was that ex-vessel prices were influenced differently (i.e., the estimated coefficients of the landings variables were statistically different) in good vs. average years of domestic shrimp production. Statistical results of estimating the simple regression model twice—using the good years of 1972, 1976, and 1977 as one data set and the remaining seven years as the second data set, and comparing the confidence intervals around the estimated coefficients—indicated that the hypothesis should be rejected at $\alpha = 0.05$. Thus, a difference does not exist between price flexibility estimates for good and average years, and this model specification was rejected (Poffenberger, 1982).

A multiple regression model was also used so that a more adequate specification of the effects that factors other than domestic supply have historically had on ex-vessel prices could be estimated (equation (2) in Poffenberger, 1982). This model was estimated using unadjusted prices and also prices that were adjusted (deflated) by the producer price index for meat, poultry, and fish. The purpose of such an adjustment was to account for the upward movement in prices over time and to permit the regression analysis to more adequately model short-term fluctuations in ex-vessel prices and landings. Empirical estimates of the adjusted and unadjusted models are close and are presented in Table 4 of Poffenberger (1982).

Price flexibilities estimated by the regression models were combined with the brown shrimp landings data simulated by Nichols (1982), assuming that the area off Texas was not closed during the regulated period. The estimated effect of the closure regulation during the period from May through August was to increase ex-vessel value by $21.5 million, or about 18 percent of the $119 million total ex-vessel value reported for this 4-month period.

Fishing Patterns

Seasonal fishing patterns were affected by the closure of the FCZ off Texas, as indicated by statistical records on the fishery. During the closure period, vessels in Texas ports either remained in port or fished in waters off the coasts of other states (mainly Louisiana). After 15 July, vessels from Texas ports and many vessels from ports in other states fished the Texas grounds. The pattern of fishing effort in 1981 was significantly different from the pattern observed in 1980 (Jones and Zweifel, 1982). However, declines in catch rates resulting from this different distribution of fishing activity, and from possible excessive concentration of effort, were not obvious. Although vessels from both Texas and Louisiana concentrated on western Louisiana grounds before 16 July, catch rates there did not appear depressed. Many vessels moved to the Texas grounds in late July and August, but they did so because of the exceptionally high catch rates there, not because of depressed catch rates on grounds off other states. The high catch rates off Texas continued through August 1981, the end of the period of observation included in these studies (Klima et al., 1982).

The disruption of historic seasonal fishing patterns resulting from the closure regulation had two effects on shore facilities—one anticipated and one unanticipated. The anticipated effect was that some vessels that historically fished off Texas in June fished off Louisiana in 1981, and a portion of these vessels landed their catch at Louisiana ports. These additional landings apparently were not large enough to have any serious effect on Louisiana's shore facilities. Temporary shortages of ice for fishing vessels were recorded at some ports, but no extended shortages occurred. Because two new ice manufacturing plants were in operation in 1981, use of the available ice capacity was actually less in 1981 than in 1980, despite the larger

catches (Ward and Poffenberger, 1982).

An unanticipated effect was the large landings at Texas ports after 15 July that resulted in difficulties in processing the catch. Vessels were delayed in unloading the catch, and on several occasions unprocessed catches had to be trucked to other localities for processing. These difficulties occurred mainly near the opening of the fishing season and were exaggerated by bad weather that caused many of the vessels to land their catches at the same time. After these initial problems, additional personnel were hired to process the larger catches, and no further major difficulties occurred.

Incidental Catch and Discards

Subtle impacts to the resource might be expected as a result of the high concentrations of fishing effort due to closure. Because of this, the NMFS Mississippi Laboratories examined the available data on fish caught incidentally to shrimping (Watts and Pellegrin, 1982), but no apparent effect on the amounts of fish caught incidentally to shrimping could be discerned from the available data. However, it should be noted that cessation of trawling for 55 days followed by very intensive fishing conceivably could have affected the numbers of shrimp predators as well as the number of shrimp themselves; Klima et al. (1982) reviewed information on the discarding of small, unmarketable shrimp.

Discarding was not a major difficulty, although some shrimp were discarded from the catches when fishing in the regulated area resumed on 16 July. This practice reportedly occurred because the crews could not process the large catches as they were brought aboard the vessels, and the problem was quickly resolved by hiring additional persons to work on the vessels.

Conclusions

We concluded from the research studies that the Texas closure provided a benefit by increasing the overall yield and value of the northern Gulf brown shrimp fishery over the short-term, from May through August, and probably increasing at least the overall yield of the long-term fishery on those cohorts affected by the closure. The increased benefits were large because of the high level of recruitment experienced in 1981. No specific attempts were made to measure who gained and who lost from this regulation, but obviously those vessels in the Texas fishery gained, and other vessels received less revenue due to price declines directly attributable to the closure. It appears from the estimates that the overall economic gains significantly outweighed the losses. The change in fishing patterns clearly affected the short-term density of shrimp populations. However, effects on animals associated with shrimp, which probably occurred, were not obvious. Thus, any long-term effects on the shrimp population itself from the change in shrimp density were not measurable in the short period of this study.

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Relative Abundance and Size Distributions of Commercially Important Shrimp During the 1981 Texas Closure

GEOFFREY A. MATTHEWS

ABSTRACT — Relative abundances of commercial shrimp, Penaeus *spp., and lengths of brown shrimp,* Penaeus aztecus, *are determined for Texas shelf waters during the 1981 Texas closure, 22 May-15 July. A total of 274 samples were collected in water where bottom depths ranged from 4 to 45 fathoms in four statistical subareas covering the Texas Gulf coast. Greatest abundances of* Penaeus *were found between 10 and 20 fathoms in each subarea. Shrimp were more abundant in the southern subareas (20 and 21) than in the northern ones (18 and 19). Relative abundances during the 1981 closure were usually greater than those calculated from the 1961-65 Bureau of Commercial Fisheries' and the 1975-80 Texas Parks and Wildlife Department's (TPWD) historical shrimp collections from similar months.*

Mean total lengths of brown shrimp in waters where bottom depths were from 4 to 10 fathoms were close to 100 mm, those in 11-20 fathoms were close to 115 mm, and those in 21-30 fathoms were close to 130 mm. When mean total lengths of brown shrimp were compared among the three data sets, means of the 1981 closure surpassed those of the two historical data sets where bottom depths were from 4 to 10 fathoms during June. Closure mean lengths between 11 and 20 fathoms were less than those from Bureau of Commercial Fisheries data and were greater than those from Texas Parks and Wildlife Department data. Closure mean lengths in 21-30 fathoms were smaller than those from both agencies' data.

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Introduction

A sustained yield of commercial shrimps off the Texas coast is economically important to Texas and to the United States. On the average, 56 percent of the brown shrimp, *Penaeus aztecus,* caught in the offshore waters of the Gulf of Mexico each year, are caught off Texas (NMFS, 1974-79). The annual shrimp harvest on the Texas Gulf coast between 1973 and 1977 has averaged 32.4 million pounds (heads-off), which amounted to an average annual contribution of $100 million to the coastal economy (at $3.10/pound). The annual shrimp harvest in Texas' offshore waters consists of 82 percent brown shrimp, about 18 percent white shrimp, *P. setiferus,* and less than 0.01 percent pink shrimp, *P. duorarum.*

Increased fishing pressure on shrimp during recent years (Christmas and Etzold, 1977; Gulf of Mexico Fishery Management Council, 1980) and the apparent reduction in the average size of shrimp caught (Caillouet et al., 1980) have caused serious concern over the possible depletion of the shrimp stock. Such concern led to the 1981 "Texas Closure," which was the simultaneous closing of the Fishery Conservation Zone (FCZ) and Texas territorial waters (Fig. 1) to shrimping

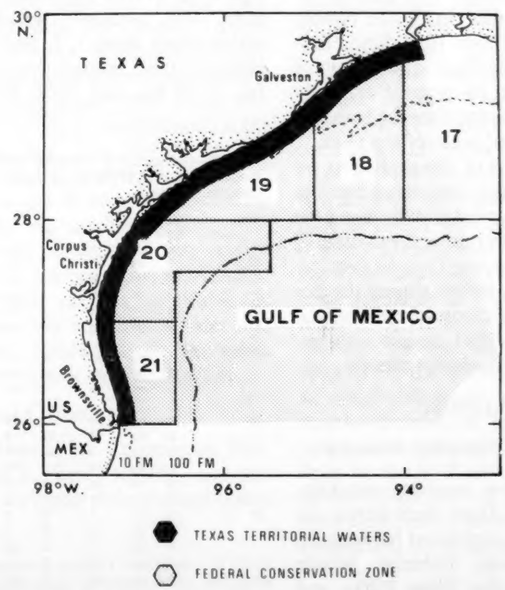

Figure 1.—A map of the Texas coast showing the four important statistical subareas (18-21), Texas territorial waters, and the Federal Conservation Zone.

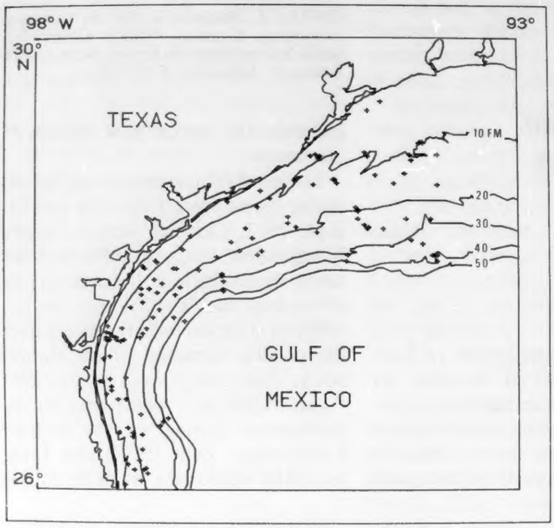

Figure 2.—Stations (+) sampled by the NMFS aboard the FRS *Oregon II* during the Texas Closure, 22 May-15 July 1981.

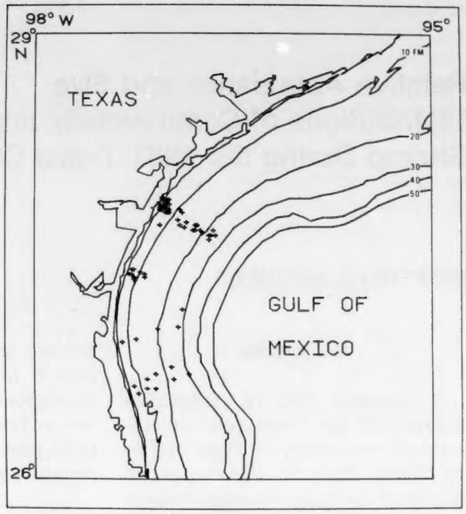

Figure 3.—Stations (+) sampled by the TPWD aboard the RV *Western Gulf* during the Texas Closure, 22 May-15 July 1981.

from 22 May through 15 July. There was a total ban on shrimping during the closure, except for the use of 25-foot or smaller nets inside bottom depths of 4 fathoms (fm) during daylight, which coincided with the annual mass migration of juvenile and subadult brown shrimp from the bays into the shallow shelf areas of the Gulf.

The objectives of this study were to: 1) Identify relative abundance distributions of commercial shrimp along the Texas Gulf coast during the closure, 2) identify relative size (length) distributions of brown shrimp during the closure, and 3) compare these distributions from the 1981 closure with historical data from similar months.

Methods

Texas Closure Sampling Procedures

A cooperative sampling program, which covered Texas shelf waters out to 50 fm, was established between the National Marine Fisheries Service (NMFS) and the Texas Parks and Wildlife Department (TPWD). There were 274 samples collected by NMFS personnel aboard the 170-foot FRS *Oregon II* and by TWPD personnel aboard the 67-foot RV *Western Gulf* (Table 1). NMFS personnel collected from 100 randomly selected sites within depth zones 1, 2, and 3, which extended from bottom depths of 0-10 fm, 11-20 fm, and 21-30 fm, respectively. They also collected from four selected sites each in depth zones 4 (31-40 fm) and 5 (41-50 fm) covering the Texas coast (Fig. 2). TPWD personnel collected in four transect areas along the south Texas coast, the major transect being at Aransas Pass (Fig. 3). All NMFS and TPWD sites deeper than 6 fm were sampled at night; TPWD sites within 6 fm were sampled during the day. To simplify data analysis, sites were grouped into four subareas that corresponded with "statistical subareas 18-21" (Fig. 1). Statistical subareas are used by NMFS to report commercial landings (Klima, 1980).

Table 1.—Distribution of 274 trawl samples taken by the NMFS (N) and TPWD (T) during the 1981 Texas Closure.

Stat. subarea	Depth zone	May N	May T	June N	June T	July N	July T
18	1	ns[1]	ns	9	ns	ns	ns
	2	ns	ns	14	ns	4	ns
	3	ns	ns	9	ns	2	ns
	4	ns	ns	2	ns	1	ns
	5	ns	ns	ns	ns	1	ns
19	1	ns	ns	15	ns	2	ns
	2	ns	ns	14	ns	ns	ns
	3	ns	ns	3	ns	ns	ns
20	1	ns	30	16	35	ns	12
	2	ns	4	22	9	ns	3
	3	ns	2	10	2	ns	1
	4	ns	ns	1	ns	ns	ns
	5	ns	ns	1	ns	ns	ns
21	1	ns	1	6	1	ns	2
	2	ns	2	19	1	ns	5
	3	ns	1	2	ns	ns	6
	4	ns	ns	2	ns	ns	ns
	5	ns	ns	2	ns	ns	ns
Sub-total		0	40	147	48	10	29
Totals		40		195		39	

[1]ns = no samples collected.

Each NMFS sample consisted of a 30-minute tow (rarely as short as 20 minutes) made with a 40-foot semiballoon shrimp trawl (2-inch stretched mesh), rigged with a tickler chain and spread by 40×96-inch doors. Each TPWD sample also consisted of a 30-minute tow (rarely as short as 15 minutes) made with either a 45-foot flat or a 47-foot semiballoon shrimp trawl (2-inch stretched mesh). Both TPWD trawls were equipped with a tickler chain and spread by 36×84-inch

doors. The NMFS samples collected between 5 and 30 fm were restricted to traversing a bottom depth change of 1 fm, and samples collected beyond 30 fm were allowed to traverse bottom depth changes of 5 fm. No such restrictions were applied to the TPWD samples; however, the duration of the tow effectively limited them to traversing only 1 or 2 fm along the bottom.

The NMFS and TPWD samples were analyzed similarly. In each sample, the *Penaeus* shrimp were culled from the total catch and separated by species. A total weight was recorded for the aggregate of each species and a subsample was drawn of either 200 specimens (only 50 specimens by the TPWD) or the entire aggregate, whichever was less. Sex and total length were determined for each individual in the subsample. Total length was measured from tip of rostrum to tip of telson. As a measure of relative abundance, a catch-per-unit effort (CPUE) value was calculated for each sample. The total weight (pounds) of *Penaeus* shrimp in the catch divided by the number of minutes towed and multiplied by 30 gives the pounds of *Penaeus* shrimp caught per 30-minute tow using a 40-foot, semiballoon shrimp trawl.

Since two different size vessels and three different size nets were used during the sampling, a series of nine paired samplings were made with the two vessels to determine if a regular

Table 2.—Total catches (pounds) and sign test results for the nine paired samplings made by the FRS *Oregon II* and the RV *Western Gulf* off the south Texas coast during the 1981 Texas Closure.

	Oregon II			*Western Gulf*		
Sample no.	Port (40-ft)	Starboard (40-ft)	Mean	Port (40-ft)	Starboard (47-ft)	Mean
1	31	28	29.5	30	29	29.5
2	32	26	29.0	43	36	39.5
3	100	69	84.5	109	109	109.0
4	142	117	129.5	101	95	98.0
5	192	153	172.5	158	138	148.0
6	175	135	155.0	170	131	140.5
7	120	114	117.0	38	48	43.0
8	35	25	30.0	34	24	29.0
9	22	27	24.5	38	37	37.5

Sign Tests:
1) Port net vs. Port net: $N=9$, $X=3$, $P=0.254$ ns.
2) Starboard net vs. Starboard net: $N=9$, $X=4$, $P=0.500$ ns.
3) Mean vs. Mean: $N=8$, $X=3$, $P=0.362$ ns.

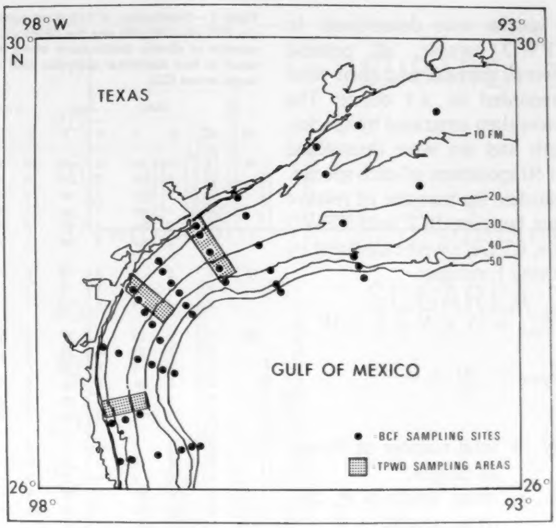

Figure 4.—Sampling sites and areas for BCF and TPWD historical shrimp data collections.

bias existed. (When a regular bias is found, a standardization factor can then be used to correct for it.) Each vessel towed two nets during each paired sampling. The *Oregon II* towed a pair of 40-foot, semiballoon shrimp trawls, and the *Western Gulf* towed a 40-foot, semiballoon trawl on the port side and a 47-foot, semiballoon on the starboard side. The 45-foot flat net was not tested, but was assumed to catch like the 47-foot net. Using the sign test, no significant differences were found between the two vessels' mean total catches[1], port net catches, or starboard net catches (Table 2). Thus, the two vessels and their nets could be considered as equivalent samplers without standardization.

Historical Collections

The Bureau of Commercial Fisheries (BCF, now NMFS) and the TPWD surveyed shrimp distributions of Texas shelf waters from 1961-65 and 1975-80, respectively. Both sampled with 45-foot gulf shrimp trawls of 2-inch stretched mesh. The BCF used 60-minute trawls taken from the *Gus III*, an 85-foot commercial shrimp trawler. Tows were taken irrespective of time of day (Lyon and Baxter, 1974). The TPWD used 15- to 30-minute trawls taken from the RV *Western Gulf*. In TPWD surveys, sites shallower than 6 fm were sampled during the day; all others were sampled at night (Cody[2]). Locations of the BCF sampling sites and the TPWD sampling areas are shown in Figure 4. The total number of samples collected during 1961-65 by the BCF and during 1975-80 by the TPWD, by statistical subareas and depth zones for May-August, is shown in Table 3.

Trawl catches were processed differently by the BCF and the TPWD. In each BCF sample, all penaeid shrimp were identified to species and counted. Length and sex of up to 100 specimens

[1]G. A. Matthews and S. L. Hollaway. A report on the distributions of *Penaeus* spp. along the Texas coast, during the 1981 Texas Closure (May-July). NMFS, SEFC Galveston Laboratory, 4700 Avenue U, Galveston, TX 77550. 80 p.

[2]Cody, T. J. 1981. Texas Parks and Wildlife Department, 715 S. Bronte Street, Rockport, TX 78382. Pers. commun.

of each species were determined. In each TPWD sample, all penaeid shrimp were removed and their total weight recorded to ± 1 ounce. The shrimp were then separated by species, and length and sex were determined for up to 50 specimens of each species. To standardize the measure of relative abundance between BCF and TPWD collections, CPUE's were calculated by the following formulae:

$$CPUE_{bcf} = \tfrac{1}{2} \times N \times L \times W$$

$$CPUE_{tpwd} = \frac{30}{T} \times C$$

where: N = total number of *Penaeus* caught,
L = mean length of *P. aztecus* caught,
W = length-weight conversion factor for *P. aztecus* using the mean length (Fontaine and Neal, 1971),
T = duration of the tow in minutes, and
C = pounds of *Penaeus* caught.

Definitions

The term "new-year-class" shrimp refers to young shrimp that are less than 1-year-old and have just migrated from the bays into the Gulf. These shrimp generally have mean total lengths between 80 and 105 mm during the May-June period (Trent, 1967; Copeland, 1965). "Previous-year-class" shrimp are defined as those that have overwintered in shallow coastal Gulf water and have mean total lengths between 125 and 180 mm during the same period. Given 30-45 days in the Gulf and sufficient food, the new-year-class shrimp are expected to grow to total mean lengths comparable to the shorter of the previous-year-class shrimp (Parrack, 1979).

In July 1981, Texas repealed its minimum size requirement for shrimp caught in the Gulf of Mexico. Prior to this date the legal limit was a minimum of 39 shrimp (heads-on) per pound, which converts to a mean total length of 114 mm. This size is used for reference in figures of length-frequency distributions.

Table 3.—Distribution of 612 trawl samples taken by the BCF (B) (1961-65) and the TPWD (T) (1975-80) for surveys of shrimp distributions along the Texas gulf coast in four statistical subareas (SS) and up to six depth zones (DZ).

		May		June		July		August	
SS	DZ	B	T	B	T	B	T	B	T
18	1	11	ns[1]	10	ns	10	ns	14	ns
	2	6	ns	9	ns	4	ns	7	ns
	3	5	ns	7	ns	2	ns	6	ns
	4	1	ns	1	ns	1	ns	2	ns
	5	3	ns	1	ns	2	ns	2	ns
	6	2	ns	2	ns	1	ns	2	ns
19	1	8	6	8	8	5	8	7	6
	2	1	5	1	6	1	6	1	4
	3	1	1	1	3	1	2	1	1
20	1	6	28	8	27	4	23	5	21
	2	10	21	8	23	6	23	8	21
	3	8	9	8	10	6	9	8	9
	4	5	ns	5	ns	5	ns	5	ns
	5	1	ns	3	ns	3	ns	3	ns
	6	1	ns	3	ns	2	ns	3	ns
21	1	2	1	4	1	3	2	3	1
	2	2	2	3	2	3	2	3	2
	3	2	2	4	2	3	2	4	2
	4	ns	ns	1	ns	1	ns	1	ns
	5	ns	ns	1	ns	ns	ns	1	ns
Subtotals		75	75	88	82	63	77	85	67
Totals		150		170		140		152	

[1]ns = no samples collected.

Results

Relative Abundance of the Genus, *Penaeus*

Abundances of *Penaeus* shrimps, all species combined, were examined relative to 1-fm depth changes across the bottom (strata) and in terms of 10-fm depth changes (depth zones) as they were found in each of the statistical subareas. The abundances during the 1981 closure by depth zones and subareas were also compared with those from BCF and TPWD historical data sets.

During the closure, several samples were taken in various 1-fm strata and their mean CPUE's determined. These samples showed considerable variability in relative abundances over short distances (Fig. 5). This variability was evident in all four subareas despite the uneven number and distribution of samples among the strata in each statistical subarea. Mean CPUE's for each stratum ranged from just over 60 pounds to under 1 pound. The highest

Table 4.—Mean CPUE's for all *Penaeus* species combined (heads-on). Collections were made during the 1981 Texas Closure.

Stat. subarea	Depth zone	No. samples	CPUE (lb.)	S.D.	PCCPN[1] (lb.)
18	1	9	14.6	11.7	1,402
	2	18	15.0	12.9	1,440
	3	9	2.1	1.6	202
19	1	17	14.3	16.5	1,373
	2	14	19.3	17.8	1,853
	3	3	5.1	0.2	490
20	1	55	12.5	12.9	1,200
	2	40	35.7	17.7	3,427
	3	15	9.6	6.3	922
21	1	10	15.5	12.1	1,488
	2	27	32.6	16.2	3,130
	3	9	13.9	8.7	1,334

[1]Calculations of potential commercial catch per 12-hour night (PCCPN) are based on 4 × the number of nets and 24 × the time interval for closure CPUE's.

means were usually located between 9 and 15 fm and the lowest were usually beyond 30 fm. Large increases and decreases in mean CPUE's occurred particularly among strata near 10 fm, but also among strata throughout the 10-20 fm ranges in all subareas. Fairly regular decreases in mean CPUE's for each stratum occurred from about 15 fm out to 45 fm, particularly in statistical subareas 20 and 21 and less so in subarea 19.

When a mean CPUE was calculated for each depth zone in each subarea, the greatest means were found for depth zone 2 in all subareas and the next highest were for depth zone 1 (Table 4). In depth zone 2, mean CPUE's for subareas 18 and 19 were similar, 15.0 and 19.3 pounds, respectively; likewise, those for subareas 20 and 21 were similar, 35.7 and 32.6 pounds. In depth zone 1, mean CPUE's were similar among all four subareas, only ranging from 12.5 to 15.5 pounds. In depth zone 3, mean CPUE's increased in fairly regular increments in line along the coast from only 2.1 pounds in subarea 18 to 13.9 pounds in subarea 21. In 7 of 12 cases, the standard deviations associated with mean CPUE's for depth zones were within ± 25 percent of their respective means. Despite the sizable standard deviations, differences in mean CPUE's for the statistical subareas and depth zones were very highly signifi-

Table 5.—Results from a two-way ANOVA testing shrimp CPUE for depth zones 1-3 in statistical subareas 18-21. CPUE values were transformed by $ln(x+1)$. Individual tows were collected in May-June during the 1981 Texas Closure.

Source of variation	Degrees of freedom	Sums of squares	F	Significance level (P)
Subareas	3	14.41	9.68	0.000***
Depth zones	2	26.56	26.76	0.000***
Interaction	6	0.87	0.29	0.940
Error	214	106.22		

*** + $P < .001$

cant when tested in a two-way ANOVA (Table 5).

For each of the historical data sets, samples collected at night in May, June, and July of each year were grouped by depth zone and statistical subarea in order to calculate overall mean CPUE's for all years combined. Data were adequate only for depth zones 1-3. Mean CPUE's of the 1981 closure data were greater than those of the BCF data in every case (depth zone in a subarea), and were greater than those of the TPWD data in all cases except for depth zone 3 in subarea 19 (Fig. 6). Standard deviations associated with mean CPUE's in all three data sets were usually substantial, suggesting that many of these apparent differences among CPUE's from data sets may not be statistically significant. Because of suspected differences in variances among the data sets for each case, the non-parametric Mann-Whitney U test (Siegel, 1956) was used to test for differences in CPUE's between data sets (Table 6). No significant differences were found where small differences in means existed (Fig. 6). Also, the large differences in means of depth zone 3 in subarea 19 and of

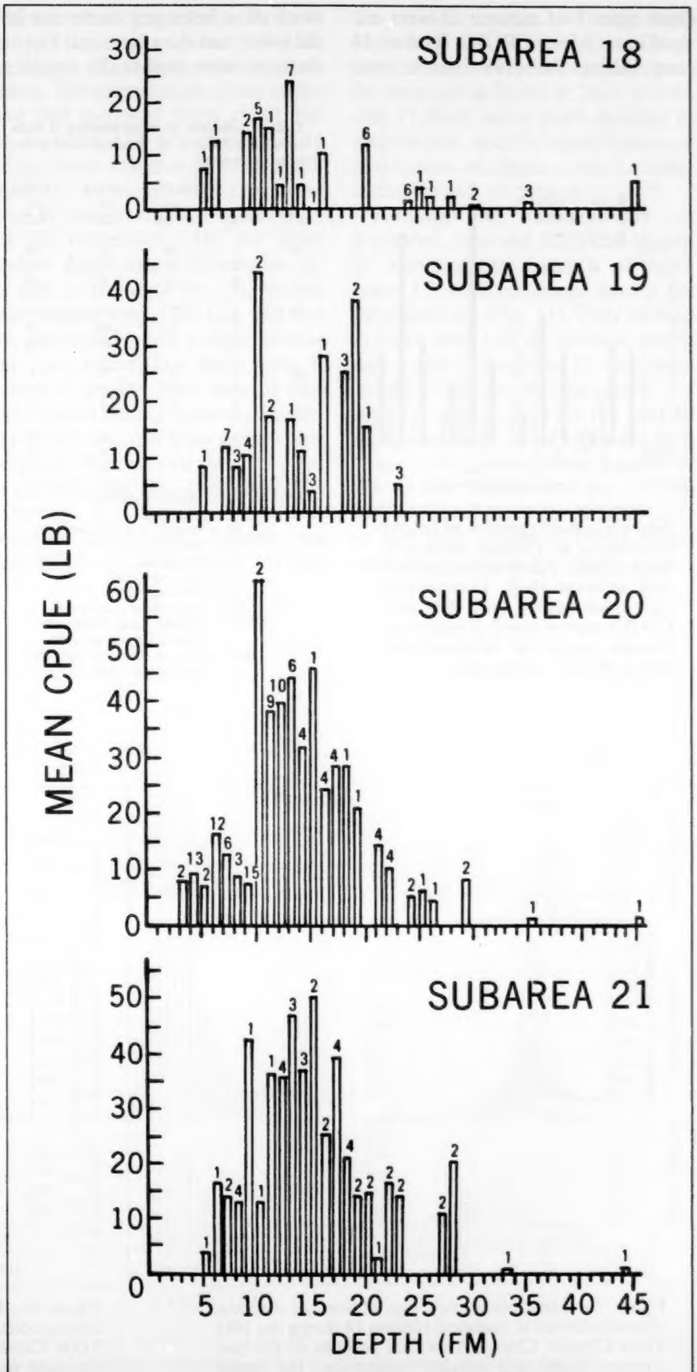

Figure 5.—Mean CPUE's of *Penaeus* shrimps from samples collected during the Texas Closure, May-July 1981, for individual 1 fm depth strata in statistical subareas 18-21 are shown by vertical bars. Numbers over each bar represent the number of samples taken in that stratum.

depth zone 1 of subarea 21 were not significant. Mean CPUE's for 6 of 12 cases during the 1981 closure were twice those belonging to the nearest of the other two data sets, and these differences were statistically significant. Thus, there was a greater than usual abundance of shrimp in Texas shelf waters during the 1981 closure period.

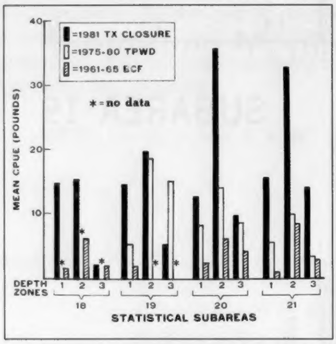

Figure 6.—A comparison of relative abundances of *Penaeus* shrimps in depth zones 1-3 (0 to 30 fm) in statistical subareas 18-21. Comparisons were made among three data sets. CPUE's were in terms of pounds of *Penaeus* caught per 30-minute tow with a 40-foot shrimp trawl.

Table 6.—Results of Mann-Whitney U tests comparing CPUE's of *Penaeus* shrimp between data sets[1].

SS	DZ	CLOS vs. TPWD	CLOS vs. BCF	TPWD vs. BCF
18	1	nd	3	nd
	2	nd	1	nd
	3	nd	0	nd
19	1	3	3	1
	2	0	nd	nd
	3	0	nd	nd
20	1	3	3	1
	2	3	3	1
	3	0	2	1
21	1	0	0	0
	2	3	2	0
	3	1	1	0

[1]Key: SS = Statistical subarea.
DZ = Depth zone.
nd = No data or insufficient data.
0 = Not significant.
1 = Significant.
2 = Very significant.
3 = Most significant.
CLOS = 1981 Texas Closure data.
TPWD = 1975-80 Texas Parks and Wildlife Department data.
BCF = 1961-65 Bureau of Commercial Fisheries data.

Length-Frequency Distributions of Brown Shrimp

Length-frequency distributions for brown shrimp caught in statistical subareas 18-21 during the 1981 closure are given in Figures 7-10. Samples taken in May (TPWD only) in subareas 20-21 clearly showed that two separate year classes of shrimp existed in these subareas. The small new-year-class shrimp that had just migrated to the shallow Gulf (depth zone 1) from the bays had mean lengths of 80 and 76 mm in subareas 20 and 21, respectively, and their lengths ranged from 48 to 144 mm (Table 7). Shrimp in depth zone 2 showed respective mean lengths of 120 and 114 mm in subareas 20 and 21. This depth zone contained previous-year-class shrimp of 130-190 mm as well as new-year-class shrimp. The previous-year-class shrimp predominated in depth zone 3, where respective mean

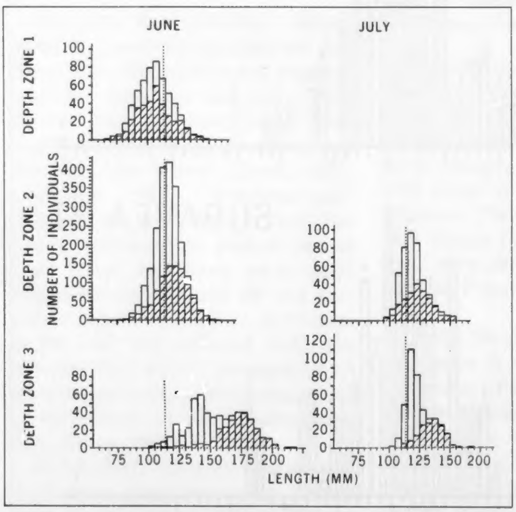

Figure 7.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 18 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

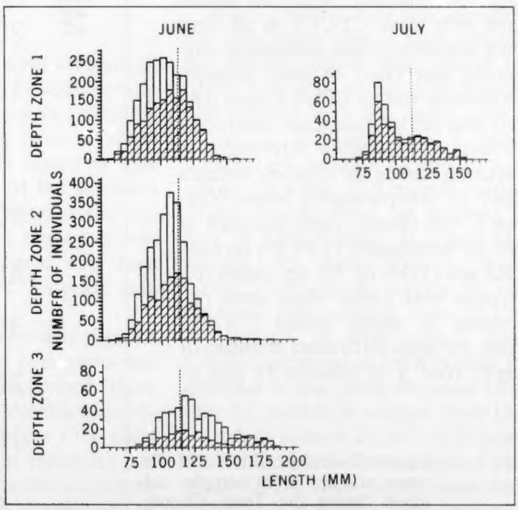

Figure 8.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 19 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

lengths were 157 and 140 mm for subareas 20 and 21.

In June, shrimp lengths in depth zone 1 in all statistical subareas showed a typical normal distribution around a mean of 100 mm. Mean lengths in subareas 18 and 19 were slightly above, while those in subareas 20 and 21 were slightly below, 100 mm. Furthermore, lengths in depth zone 2 in all subareas also appeared normally distributed around a higher mean (110 mm) than in zone 1. Means for subareas 18 and 21 were slightly above 110 mm and those in subareas 19 and 20 were slightly below. According to length-frequency distributions, previous-year-class shrimp comprised about 80 percent of the stock in depth zone 3 of subarea 18, but only about 20 percent of the same in subareas 19-21.

Length-frequency distributions in July showed the continued presence of small new-year-class shrimp. In depth zone 1 of statistical subareas 19 and 20, two waves of new-year-shrimp were evident. The mean length of the earlier wave had increased from about 100 mm to about 120 mm in subarea 19 and to about 110 mm in subarea 20. Means of the more recent wave were about 90 and 80 mm for subareas 19 and 20, respectively. On the other hand, in depth zone 2 of subareas 18, 20, and 21 (no data for 19), shrimp mean lengths were 120, 122, and 113 mm, respectively, only a slight increase over June values. For depth zone 3, changes in lengths from June to July stocks varied among subareas. In subarea 18 the new-year-class shrimp now comprised 80 percent of the stock, and the previous-year-class comprised only 20 percent. This increase in the new-year-class component lowered the mean length to 120 mm from 151 mm the previous month. Although only one sample was taken in subarea 20, it showed only new-year-class shrimp of the same size as found in June. In subarea 21 there was a slight decrease in mean length, and the length-frequency distribution of depth zone 3 closely resembled that of zone 2.

Although May statistics were not compared, June and July mean lengths of brown shrimp in each of depth zones 1-3 were compared among the three data sets (Fig. 11). Only in June in depth zone 1 of all subareas and in depth zone 2 of subarea 21 were mean lengths of brown shrimp greater for the 1981 closure than for the 1961-65 BCF data; in all other cases the BCF means were greater. Mean lengths of the brown shrimp in the 1975-80 TPWD data were very close to those of the 1981 closure. TPWD means were slightly lower for depth zones 1

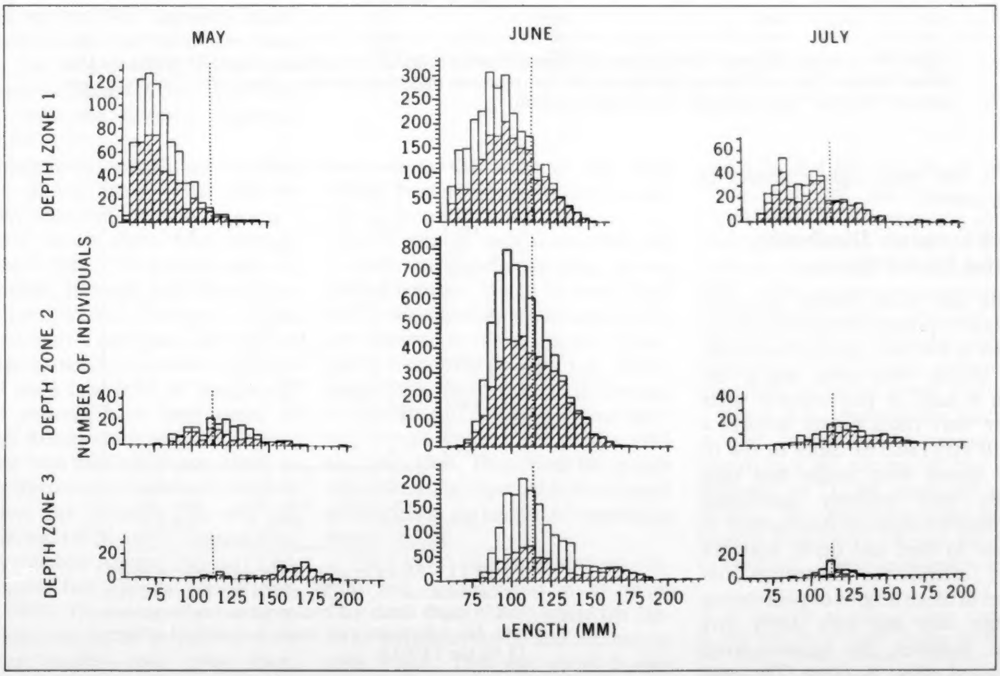

Figure 9.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 20 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

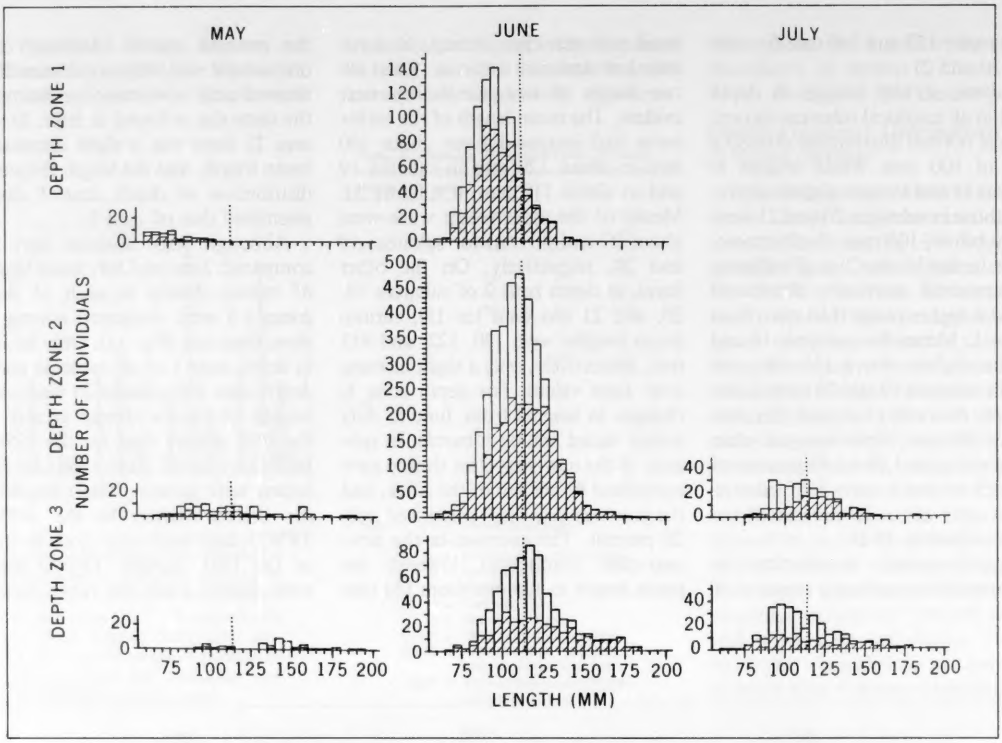

Figure 10.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 21 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

and 2, but were slightly greater in depth zone 3.

Length-Frequency Distribution of Other Penaeid Species

Pink and white shrimp accounted for about 5 percent of the total shrimp catches in the four statistical subareas. Pink shrimp were taken mainly between 4 and 20 fm, whereas white shrimp were taken mainly between 4 and 10 fm (Table 8). Since so few of these species were caught and their catches were unevenly distributed, their length-frequency distributions in relation to time and depth were not firmly established. Sometimes, increases in mean lengths of pink shrimp through time and with depth were found; however, the opposite trend was noted about as often. The same was true for white shrimp. Length-frequency distributions of pink shrimp showed a mixture of small new-year-class shrimp with large previous-year-class shrimp in all depth zones and subareas where 10 or more shrimp were measured. On the other hand,

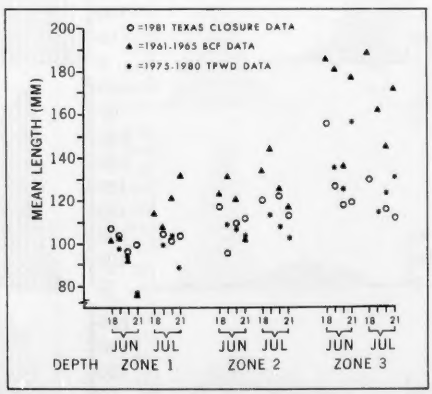

Figure 11.—Mean lengths of *Penaeus aztecus* in statistical subareas 18, 19, 20, and 21 for June and July and in depth zones 1-3 compared among three data sets. No collections were made in statistical subarea 18 by the TPWD.

length-frequency distributions showed that white shrimp stocks were composed almost exclusively of large previous-year-class shrimp. Only in June in subarea 21 and in July in subarea 20 were a few small new-year-class white shrimp found.

Data were insufficient to warrant comparisons of lengths of pink and white shrimps among the three data sets.

Discussion

In 1981, for the first time, both the Texas territorial waters and the Fishery Conservation Zone were closed to shrimping during the spring period of brown shrimp migration. The main purpose of this closure was to prevent the wasteful catching and discarding of shrimp below marketable size. Although this study's primary objective was to determine the effects of the 1981 closure on the shrimp stock, with special reference to abundance and length-frequency changes through time and location, a few specific questions should also be considered: 1) How typical was the 1981 migratory stock? 2) How closely did the closure data depict the stock as reflected by later commercial catches? And, 3) to what extent were the closure's objectives fulfilled?

Table 7.—Total length (mm) statistics for brown shrimp derived from NMFS and TPWD trawl samples from depth zones 1-5 and statistical subareas 18-21 along the Texas shelf during the 1981 Texas Closure.

	Statistical subareas									
	18		19		20			21		
Item	June	July	June	July	May	June	July	May	June	July
Depth Zone 1: 0-10 fm										
No. measured	560		2,320	406	773	2,698	401	47	902	2
Length										
Min.	70		60	72	48	54	67	58	58	95
Max.	146		157	152	144	177	197	104	149	113
Mean	107		104	104	80	96	101	76	99	104
S.D.	13		16	18	14	18	21	18	13	8
Depth Zone 2: 11-20 fm										
No. measured	2,165	446	2,901		192	6,695	150	100	3,785	246
Length										
Min.	78	97	56		78	63	78	69	58	76
Max.	157	153	184		198	179	166	187	188	182
Mean	117	120	105		120	109	122	113	112	113
S.D.	11	9	36		19	17	18	26	16	16
Depth Zone 3: 21-30 fm										
No. measured	555	410	517		95	1,711	50	47	703	300
Length										
Min.	104	110	78		98	67	86	93	68	64
Max.	216	172	189		192	213	147	191	185	177
Mean	156	130	126		157	118	116	140	119	112
S.D.	21	10	22		23	21	11	23	20	21
Depth Zone 4: 31-40 fm										
No. measured	30	3				1			32	
Length										
Min.	155	182				146			94	
Max.	216	208				—			180	
Mean	177	192				146			131	
S.D.	16	14				—			24	
Depth Zone 5: 41-50 fm										
No. measured		49				8			4	
Length										
Min.		123				159			95	
Max.		223				192			147	
Mean		168				169			130	
S.D.		20				12			20	

Emigration of juvenile and subadult brown shrimp from Texas Bays to shallow waters in the Gulf of Mexico typically occurs from May through July each year. The typical peaks in emigration, through tidal passes that have been studied, occurred in late May or early June. Also, this exodus apparently occurs in waves superimposed on a base level of emigration. These patterns have been noted in Bolivar Roads which connects Galveston Bay with the Gulf (Trent, 1967), in Cedar Bayou which connects Mesquite Bay and San Antonio Bay with the Gulf (King, 1971), and in Aransas Pass which connects Aransas Bay and Corpus Christi Bay with the Gulf (Copeland, 1965). The timing of the emigrations held true for all six years covered by these studies—1963, 1964, 1966, 1968, 1969, and 1970.

Furthermore, the sizes of emigrating brown shrimp showed considerable uniformity through the various years and among the areas of the three studies cited above. Mean total length for the brown shrimp in early June was near 85 mm in each study, with the majority of these emigrating brown shrimp between 75 and 95 mm. Trent (1967) was the only one to note a definite increase in mean lengths of emigrants from May through July. Copeland (1965) reported small differences in mean lengths of brown shrimp moving through Aransas Pass in May 1963 and May 1964. Thus, both the month and year can be expected to show small differences in the lengths of emigrating brown shrimp.

The TPWD also sampled shrimp directly off Aransas Pass in 10 fm in June 1968 (King, 1971) where the majority were between 80 and 100 mm in total length. This was about 5 mm greater than shrimp migrating through Cedar Bayou at the same time. In May 1981 the new-year-class brown shrimp in depth zone 1 were averaging between 76 and 80 mm. Based on this "pass to 10-fm" size change on the typical sizes of the emigrating shrimp, and on the sizes of the brown shrimp in depth zone 1 and in May and June 1981, it appears the early establishment of the closure was a wise step. This measure protected the large wave of emigrating small brown shrimp that must have occurred in late May.

Klima et al.[3] analyzed the July commercial brown shrimp catches and found over 40 percent of the catch belonged to 31-40 heads-off count shrimp. This converts to total lengths ranging from 130 to 140 mm according to Fontaine[4]. These total length values

[3]E. F. Klima, K. N. Baxter, and F. J. Patella. A review of the offshore shrimp fishery and the 1981 Texas closure. NMFS, SEFC Galveston Laboratory, 4700 Avenue U, Galveston, TX 77550. 68 p.

[4]C. T. Fontaine. A chart showing tail lengths and total lengths for each shrimp count category. NMFS, SEFC Galveston Laboratory, 4700 Avenue U, Galveston, TX 77550. 10 p.

Table 8.—Total length (mm) statistics for pink and white shrimp derived from NMFS and TPWD trawl samples from several depth zones and statistical subareas 18-21 along the Texas shelf during the 1981 Texas Closure.

	Statistical subareas									
	18		19		20			21		
Item	June	July	June	July	May	June	July	May	June	July
Pink shrimp, *Penaeus duorarum*										
Depth Zone 1: 0-10 fm										
No. measured	68		100	2	193	3,171	19	16	312	111
Length										
Min.	104		88	107	71	84	102	52	74	104
Max.	178		166	122	155	178	181	143	176	154
Mean	129		118	114	101	127	135	116	116	128
S.D.	13		12	7	16	11	18	23	15	10
Depth Zone 2: 11-20 fm										
No. measured	339	22	244		3	6	0	10	155	0
Length										
Min.	98	93	80		84	97	—	78	59	—
Max.	198	127	175		166	148	—	116	159	—
Mean	135	113	119		114	124	—	98	102	—
S.D.	15	7	15		37	17	—	10	19	—
Depth Zone 3: 21-30 fm										
No. measured	3	5	14		0	0	0	0	1	0
Length										
Min.	138	110	90		—	—	—	—	115	—
Max.	175	151	128		—	—	—	—	—	—
Mean	151	129	104		—	—	—	—	115	—
S.D.	17	14	9		—	—	—	—	—	—
White shrimp, *Penaeus setiferus*										
Depth Zone 1: 0-10 fm										
No. measured	119		356	142	453	462	154	0	1	0
Length										
Min.	137		139	155	125	138	73	—	82	—
Max.	192		205	210	197	198	190	—	—	—
Mean	164		173	176	165	172	167	—	82	—
S.D.	11		12	11	15	10	18	—	—	—
Depth Zone 2: 11-20 fm										
No. measured	37	0	0		2	22	0	0	1	0
Length										
Min.	153	—	—		158	154	—	—	161	—
Max.	193	—	—		169	197	—	—	—	—
Mean	172	—	—		164	175	—	—	161	—
S.D.	10	—	—		5	11	—	—	—	—

were slightly larger than the July means calculated from closure data for depth zones 2 and 3 in all subareas for which data were available, and are within the expected size range that shrimp would attain given the 2- to 3-week growing period between the early July closure sampling and the late July commercial shrimping. This observation provides supportive evidence that the closure sampling and analyses were fairly accurate in depicting sizes of brown shrimp in the stock.

The 1981 sampling during the closure indicated a high relative abundance of shrimp. It appeared that the 1981 harvest would be bountiful once shrimping began. Based on catch-per-unit-effort statistics from the closure samples, the greatest concentrations of shrimp were found in depth zone 2 of each of the four subareas covering the Texas coast. The second largest concentrations were in depth zone 1, followed by depth zone 3, and still lesser concentrations were found at deeper levels. CPUE's for depth zone 2 were about twice as great in subareas 20 and 21 as in 18 and 19. It is uncertain whether this difference was due to a greater influx of immigrant shrimp from southern bays or whether it was a result of preferences for depths encompassed by depth zone 2 by the 95- to 125-mm size shrimp, coupled with narrower and smaller bottom areas for depth zone 2 in subareas 20 and 21. A third possibility is that the majority of samples in subareas 20 and 21 were taken directly out from the major tidal passes and thus in the mainstreams of the migrating shrimp. Many samples were collected directly in front of Aransas Pass in statistical subarea 20, but not in front of the passes in subarea 21. Since both 20 and 21 had high CPUE's, it is most likely that the first two explanations were of greater importance in determining the CPUE's for the subareas than was the third explanation.

Commercial shrimp catches for July and August 1981 efforts along the Texas coast were outstanding, amounting to 10.3 million pounds (heads-off) in July and 14.6 million in August, according to Klima et al. (footnote 3). They calculated the mean July CPUE by shrimpers in Texas at 1,125 pounds (heads-off) per 12-hour shrimping night. Additionally, they noted the maximum CPUE's were found in subareas 20 and 19 in July. Based on the closure samplings in June and July in depth zones 1-3, the potential commercial catch per 12-hour shrimping night was calculated to be 1,522 pounds (heads-on). This value shows very close agreement for the two separate calculations and is an additional indication that the closure sampling was able to depict fairly well the abundance of the brown shrimp stock along Texas. On the other hand, it was somewhat disconcerting to note that the high CPUE's found during the closure for statistical subarea 21 were not evident in the commercial catches during July. Likewise, another point of difference is that the high CPUE found by shrimpers in subarea 19 in July was not found during the closure. Both sampling design and shrimp migrations along the coast may have been responsible for these discrepancies.

Major contributions of this 1981 closure study include delineation of the abundance distribution of brown shrimp based on catch-per-unit-effort and description of the length-frequency distributions of the brown shrimp on the major commercial shrimping grounds off Texas. As a further contribution, the changes in mean lengths of these shrimp stocks were identified, and the causes of these changes were explained through the analyses of length-frequency distributions of brown shrimp. The minor discrepancies made in depicting the stocks in specific areas have suggested a revision of the future sampling design. On the whole, however, it appears the closure

accomplished its objectives: It protected the small new-year-class shrimp from harvest until they had grown to marketable size, and it appears to have enhanced the total catch for the season.

Summary

1) Relative abundance measured by mean CPUE's for individual 1-fm depth changes showed considerable uniformity in the size of the *Penaeus* shrimp stock at 5-10 fm in all four subareas. Brown shrimp comprised 85 percent of this shrimp stock.

2) The variability in mean CPUE's from one individual single-fathom depth stratum to another in depth zone 2 (11-20 fm) showed considerable patchiness in the *Penaeus* shrimp stock over these small depth changes and short distances.

3) Despite their patchiness, *Penaeus* shrimp stocks were greatest in depth zone 2 in all statistical subareas, and were second highest in depth zone 1. Mean CPUE's for depth zone 2 were 35 and 32 pounds in subareas 20 and 21 (southern), respectively, and were 15 and 19 pounds in subareas 18 and 19 (northern), respectively. Mean CPUE's for depth zone 1 in the four subareas were between 12 and 15 pounds.

4) Mean CPUE's for each of depth zones 1-3 in each subarea were greater during the 1981 closure than during the 1961-65 BCF collections or during the 1975-80 TPWD collections, with only one exception. In 8 of 10 cases (depth zone in a statistical subarea), the 1981 closure CPUE's were significantly greater than those of the 1961-65 BCF data set, and in 5 of 9 cases the closure CPUE's were significantly greater than those of the 1975-80 TPWD data set. In all other cases, there were no significant differences between 1981 closure CPUE's and corresponding CPUE's from the other two historical data sets.

5) Length-frequency distributions in May showed small new-year-class brown shrimp in depth zone 1, a mixture of new-year-class and previous-year-class shrimp in depth zone 2, and mostly previous-year-class shrimp in depth zone 3. These findings were for subareas 20 and 21 only; no data were obtained in subareas 18 and 19 for May.

6) Length-frequency distributions in June showed new-year-class brown shrimp in depth zone 1 of all subareas. In depth zone 2 the stock was composed of new-year-class shrimp which were 5-10 percent longer than those in depth zone 1. In depth zone 3 the stock was composed of both year classes; new-year-class shrimp comprised 20 and 80 percent of the stocks in subarea 18 and subareas 19-21, respectively.

7) Length-frequency distributions in July showed new-year-class shrimp comprising almost the entire stock throughout depth zones 1-3. In subareas 19 and 21, probably two waves of new-year-class shrimp were evident in depth zone 1.

8) Mean total lengths of brown shrimp increased with depth out to 40 fm in May and in June in all depth zones in all subareas where data were available. In July, mean lengths increased only from depth zone 2 to zone 3 in subarea 18 and from depth zone 1 to zone 2 in subareas 20 and 21. Offshore migration of small new-year-class shrimp counteracted increases from growth in deeper zones to maintain or decrease mean lengths in these stocks in deeper waters, especially in July.

9) In comparing brown shrimp mean total lengths for June, those of the 1981 closure were: A) Larger than those of the historical BCF and TPWD data sets in depth zone 1, B) smaller than those of the BCF in depth zone 2, and C) smaller than both BCF and TPWD means in depth zone 3.

10) In comparing brown shrimp mean total lengths for July, those of the 1981 closure were smaller than those of the BCF data and larger than those of the TPWD in subareas 19 and 21 for depth zone 1. In depth zone 2, the 1981 means were smaller than the BCF's and larger than the TPWD's in all depth zones in all subareas where data were available. In depth zone 3, the 1981 means were smaller than those of the BCF and the TPWD where data was available.

11) Pink shrimp accounted for less than 5 percent of the total number of *Penaeus* caught during the 1981 closure sampling. Mean total lengths were similar to those of brown shrimp, and in subareas 20 and 21 where most pinks were caught, they showed an increase in mean lengths with time. New-year-class and previous-year-class pinks were present in most cases.

12) White shrimp comprised less than 1 percent of the number of *Penaeus* caught during the 1981 closure, mainly because their main habitat —2-6 fm—was rarely sampled. About 98 percent of the white shrimp were previous-year-class shrimp.

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A Review of the Offshore Shrimp Fishery and the 1981 Texas Closure

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Introduction

The Texas closure management measure involved closure of the brown shrimp fishery for the first time from the coastline to 200 miles off Texas and was in effect from 22 May to 15 July 1981. The evaluation of the impact of this management measure has been scrutinized by a series of studies reported in this issue of the *Marine Fisheries Review*. In our paper we review the Texas and Louisiana offshore shrimp fisheries and describe the catch, relative abundance, and recruitment to the offshore fishery from June through August 1981 and compare the 1981 fishery with the fisheries of earlier years.

Statistics describing the U.S. Gulf of Mexico shrimp fishery began in 1956, and the procedures used to collect these data are described by Klima (1980). These statistics, compiled by the Southeast Fisheries Center (SEFC) Technical and Information Management Services (TIMS), consisting of catch by statistical subarea (Fig. 1) and effort data, were used to analyze the effects of the Texas closure. In 1981, increased emphasis was exerted to collect catch and effort statistics from June through August. Location, catch, and amount of fishing effort expended are obtained by interviewing fishing captains at the termination of their trips. In 1981, the captains of at least 50 percent of the offshore vessels were interviewed to obtain this specific information. However, in prior years the interview level was usually less than 30 percent.

All catch data were recorded as heads-off by species and size category by statistical subarea, depth zone, and month. These data were used to compile catch per unit effort (CPUE) per 24 hours of fishing and were reported in "Fishery Statistics of the United States" and "Shrimp Landings" (USFWS, 1956-70a, b; NMFS, 1970-79a, b). In addition, surveys of inshore waters of Texas and Louisiana were analyzed by the Texas Parks and Wildlife Department (TPWD) and the Louisiana Department of Wildlife and Fisheries (LDWF) to determine recruitment to the offshore fisheries.

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ABSTRACT — Prohibition of shrimp fishing within 200 miles of the Texas coast on 22 May 1981 resulted in large brown shrimp catches off Texas when the season reopened on 15 July. Catch per unit effort off Texas in late July and August 1981 ranged from 1,349 to 2,250 pounds per fishing day, compared with only 820 to 858 pounds per fishing day for the Louisiana offshore brown shrimp fishery. The July-August 1981 relative abundance (CPUE) off Texas was greater than during similar time periods for any other year. Shrimp caught and landed off Louisiana were also predominantly smaller than those caught and landed off Texas.

Recruitment from Texas bays to the offshore fishery appeared average to good, but was not sufficient to account for the outstanding abundance levels found offshore. The closure of Texas waters to fishing appears to have been a major reason for the large catches and high catch rates in July and August off Texas in 1981.

Figure 1.—Locations of statistical subareas (no. 12-21); The Texas territorial waters (solid black band); and the Federal Fisheries Conservation Zone (striped area).

Review of the Shrimp Fishery

Fishery Background

Shrimp have been fished commercially in the Gulf of Mexico since the latter part of the 19th century; commercial records date back to 1880 for Texas and Louisiana. Prior to 1900, shrimp were usually caught with haul seines, which were large, unwieldy nets extending up to 1,800 feet long. These nets required up to 20 men to operate and could be used only in shallow waters; thus many stocks of shrimp were used only seasonally, if at all. This factor appears to have been important in limiting the early growth of the fishery.

Gulf Coast shrimping in its present form began with the introduction of the otter trawl in 1915. This gear could be fished in deeper waters by small crews and proved superior to the haul seine. By 1930, virtually all Gulf shrimpers were trawling rather than seining. The otter trawl has changed little in design since its introduction, although size has varied considerably depending on size and design of the towing vessel. "Single-rigged" trawlers tow one large trawl, which may be as wide as 120 feet at the mouth; "double-rigged" trawlers tow two trawls varying from 40 to 75 feet wide at the mouth (Knake et al., 1958; Captiva, 1966, 1970). The double-rigged arrangement proved to be more effective in catching shrimp than a large single trawl and was used on virtually all large shrimp vessels until the early 1970's.

Commercial fishermen began testing and using twin trawl systems (four trawls are towed simultaneously, from each side and to the stern of the vessel) in 1972. The twin trawl concept (Harrington et al., 1972) has since gained wide acceptance by Gulf and Atlantic coast fishermen and is the most common gear used today on offshore Gulf vessels. Approximately 64 percent of the Texas offshore fishermen use twin trawls (Table 1).

Vessels used in the shrimp industry have varied in size and type from small skiffs to steel-hulled vessels over 100 feet long. It is convenient to divide today's shrimp vessels into two distinct classes: 1) Inshore and 2) offshore vessels. Inshore vessels, which trawl the shallow bays and adjacent offshore waters, are usually wooden hulled, shallow draft boats under 45 feet long, powered by gasoline or diesel engines of less than 140 horsepower (HP). Offshore vessels are constructed from either wood, reinforced fiberglass, aluminum alloy, or steel. These vessels average between 50 and 90 feet long and are powered by diesel engines of up to 750 HP. Such vessels are usually capable of extended trips, which may last as long as 30-50 days. Even larger vessels have been built in recent years.

Biological Background

Although nine species of shrimp contribute to the Gulf fishery, only brown, *Penaeus aztecus,* white, *P. setiferus,* and pink, *P. duorarum,* shrimp are caught in commercial quantities. These shrimp are found in all Continental Shelf waters in the U.S. Gulf of Mexico inside 60 fathoms (fm). The greatest portion of the reported offshore catch of brown shrimp is taken in 11-20 fm, that of white shrimp in 5 fm or less, and that of pink shrimp in 11-15 fm. Highest offshore densities of brown shrimp occur off the Texas/Louisiana coast, the highest densities of white shrimp occur off the Louisiana coast; and highest densities of pink shrimp occur off the southwest coast of Florida.

In Texas and Louisiana only brown, white, and pink shrimp are commercially important and collectively make up over 99 percent of the annual shrimp catch. In this review, we have considered only brown, white, and pink shrimp. These species have a similar life cycle in which spawning occurs offshore; however, the times that recruits enter the fishery differ for the three species. Eggs generally hatch into planktonic larvae after 10-12 hours. During the next 12-15 days, these larvae metamorphose through additional planktonic stages into postlarvae. Upon entering the estuaries, these postlarvae become benthic and develop quickly into juvenile shrimp.

Table 1.—Fishing gear and number of vessels landing in Texas (1980)[1].

Number of nets	Average net size (yards)	Number of vessels
1	19.4	645[2]
2	38.8	579
4	48.5	1,028

[1]1980 Operating Units Inventory, Technical and Information Management Services, Galveston Office, Southeast Fisheries Center.
[2]Almost exclusively inshore fishing vessels.

Brown shrimp begin entering Texas estuaries in mid-February and continue through July, depending on water temperatures and environmental conditions. Several "waves" of postlarvae may enter the estuary, but peak recruitment occurs in March and April and again in September (Baxter and Renfro, 1967). The postlarvae use the estuary as a nursery and eventually migrate back into the Gulf at the subadult stage. Emigration begins in May with peak emigration periods usually during May, June, and, to some extent, July. While in the bays, the juvenile shrimp may be exposed to recreational and commercial fishing during the spring and summer months. These fisheries are controlled by the respective states.

White shrimp postlarvae begin entering the Texas estuaries in May, with a peak in June and September and with some recruitment continuing until November (Baxter and Renfro, 1967). These postlarvae use the estuaries as nurseries during summer and fall and grow to harvestable size (120-160 mm total length) in the bays, where they are exploited by recreational and commercial fishermen during late summer. White shrimp emigration is governed by size and environmental conditions within the given bay systems. Usually they begin emigrating in late August and September, when the offshore commercial fishery exploits this resource. The average life span of these three species is thought to be about 18 months, although some live for 3-4 years.

Pink shrimp also are commercially important to the Texas fishery but are

usually recorded as brown shrimp, since they are not sorted by processors and are more difficult to distinguish from brown shrimp than white shrimp. South Texas apparently has a major pink shrimp fishery in which postlarvae enter the bay systems in early winter, use the bay systems as a nursery, and emigrate offshore in March and April, where they are harvested by the commercial fleet. The percentage of pink shrimp landed is not known. We assume that it does not constitute more than 10 percent of the total shrimp catch off Texas.

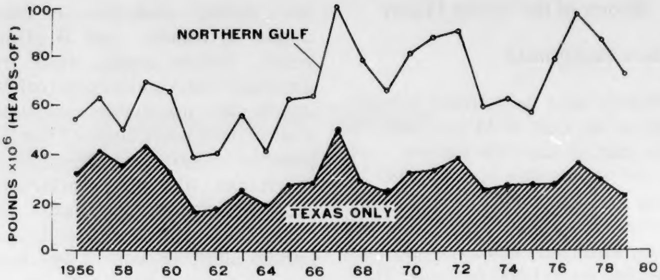

Figure 2.—Average annual landings of brown shrimp for Texas only and for the northern gulf (including Texas, Louisiana, Mississippi, Alabama, Florida, and Mexico) for the period 1956-79.

Production and Regulations

During the early years of the fishery, Gulf shrimpers caught only white shrimp, as brown and pink shrimp could not be marketed due to their darker color. From 1880 through 1918, the annual white shrimp catch along the Texas coast averaged 172,000 pounds, heads-off[1], and 5.9 million pounds off Louisiana. Although records are incomplete during this time, by 1923 the Texas catch increased to about 2.2 million pounds and by 1927 had reached 7.4 million pounds. The Louisiana catch in 1927 was 26 million pounds. From 1927 to 1945, Texas landed an average of 7.8 million pounds annually of predominantly white shrimp, and Louisiana landed an average of 40.5 million pounds. After World War II, however, large concentrations of brown and pink shrimp were discovered off the coasts of Texas and Florida. The Texas shrimp catch increased dramatically from 13.8 million pounds in 1948 to a peak of 58 million pounds in 1954. By 1956, the Bureau of Commercial Fisheries began to record catch statistics accurately for the entire Gulf of Mexico.

Brown shrimp predominate the Texas catch, although there is a continuing white shrimp fishery. From 1956 through 1976, the average catch of white shrimp was approximately 9.5 million pounds, with a low of approximately 2.3 million pounds in 1957 and a high of 14.9 million pounds in 1973 (USFWS, 1956-1970a; NMFS, 1971-1979a). The average Louisiana white shrimp catch for 1956-76 was 20.2 million pounds.

Brown shrimp have been the main focal point for the Texas fishery since adequate recordkeeping began in 1956, averaging approximately 28.6 million pounds for the timespan through 1979, i.e., brown shrimp landed in Texas comprise about 50 percent of the brown shrimp catch in the northern Gulf of Mexico (USFWS, 1956-1970b; NMFS, 1971-1979b). The peak year was 1967, when almost 50 million pounds were caught off Texas; low landings occurred in 1961, 1962, and 1964, when an average of slightly less than 20 million pounds was caught off Texas (USFWS, 1956-1970b). Average annual production from 1970 to 1980 increased to 30.4 million pounds, indicating an increase in brown shrimp production compared with the 20-year average from 1960 (Fig. 2). Production of brown shrimp from bay waters in Texas since 1971 was less than 9 percent of the total annual Texas catch. Fluctuations in catch are notable during the last 20 years and have caused considerable economic hardship to the fishery.

Shrimping regulations vary by states along the Gulf coast and, in fact, the harvesting strategy differs significantly between Louisiana and Texas (Christmas and Etzold, 1977). These two states account for approximately 75 percent by weight of the shrimp landed from the U.S. Gulf of Mexico. In Texas, shrimping regulations generally restrict the landing of small shrimp, whereas in Louisiana there are few restrictions on the taking of small shrimp. The overall results of these two diametrically opposed regulatory schemes are that in Texas the bulk of the catch comes from an offshore fishery and consists mostly of large shrimp, whereas in Louisiana, there is a substantial inshore fishery producing a large volume of small brown and white shrimp. The average ex-vessel value per pound for brown shrimp for 1961 through 1975 was 1.6 times higher in Texas than in Louisiana. Further, the annual total weight and value of brown shrimp landings (Fig. 3) have been greater in Texas than in Louisiana (Caillouet and Patella, 1978).

To protect the small emigrating brown shrimp during peak recruitment periods, Texas enacted a "closed" season in 1959 to enhance shrimp catches by allowing the shrimp to grow to a large size before they were exploited. The Texas law provides for a 45-day closed season in all offshore waters out to 3 marine leagues with a general closing date of 1 June and opening date of about 15 July (Table 2), with the provision that the season can be either opened earlier due to an excess amount of shrimp emigrating early, or closed later. However, the season cannot extend for more than 60 days. Texas is the only coastal state to initiate such a

[1]All catches reported in pounds, heads-off.

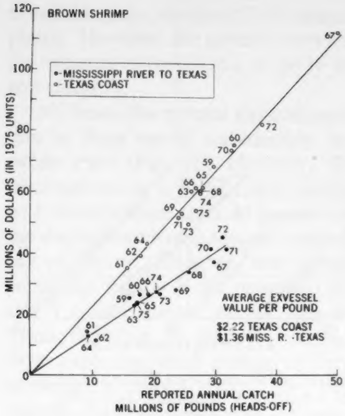

Figure 3.—Relationship between average ex-vessel value per pound of brown shrimp landings and total annual catch for the years 1959-75 on the Texas and Louisiana (Mississippi River to Texas) coasts (Caillouet and Patella, 1978).

Table 2.—Historical dates of the closed shrimp season off Texas[1].

Year	Date closed	Date open
1960-66	1 June	15 July
1967	17 May	1 July
1968-71	1 June	15 July
1972	17 May	1 July
1973-75	1 June	15 July
1976	17 May	15 July
1977-80	1 June	15 July
1981	22 May	15 July

[1]C. E. Bryan, Texas Parks and Wildlife Department, Austin, Tex., pers. commun., 1981.

law, and it has been in effect for 21 years. During the closed season, Texas permits a daytime white shrimp fishery inside 4 fm, but vessels (or boats) are only permitted to use a single trawl not larger than 25 feet between the trawl doors. In addition, Texas has had restrictions on the size of shrimp landed and prevents the landing of shrimp smaller than 65 count, heads-off (i.e., 65 shrimp/pound) during the regular open season.

In 1981, along with the promulgation of the Shrimp Fishery Management Plan (NOAA, 1980), the size restriction on brown shrimp was eliminated in Texas. In addition, Texas allows inshore fishing in its bays and estuarine systems from 15 May to 15 July and allows a catch of 300 pounds/day, heads-on, without size restrictions. At present, no size count is in effect for the inshore fishery. Also, a bait shrimp fishery is open year-round and each vessel is permitted to take up to 150 pounds/day, half of which must be kept alive.

Louisiana Fishery

In Louisiana, shrimp fishing in inside waters is regulated by the Louisiana Department of Wildlife and Fisheries. This agency, like the Texas Parks and Wildlife Department, has an intensive sampling program that is the basis upon which they recommend to the Louisiana Wildlife and Fisheries Commission the opening and closing of the brown and white shrimp season in inside waters. The brown shrimp season opens between 15 and 25 May, with the specific date based on the average size expected on the opening date. The season may not run for more than 60 days. To protect juvenile white shrimp, the Commission has the authority to recommend closure of the brown shrimp season by regional areas if large concentrations of juvenile white shrimp are present in the specific bay systems. In 1981, the brown shrimp season was opened on 18 May, and inside waters west of the Mississippi River were closed to brown shrimp fishing on 8 July.

The brown shrimp catch (1977-80) from inside waters ranged from 28 percent to 37 percent of the total annual brown shrimp catch for the State of Louisiana. Peak production from inside waters occurs in May and June, with reduced production in July and August. The total annual brown shrimp production in Louisiana (subareas 13-17) from 1960 to 1979 ranged from a low of 7 million pounds in 1962 to a high catch of 46 million pounds in 1977 and 1978. The average annual production during the period 1960-79 was approximately 24.7 million pounds. Since 1977, over 50 percent of the annual Louisiana brown shrimp production has occurred in June, July, and August.

The offshore fishery from June through July, based on 1979 data, is usually concentrated in statistical subareas 13 and 15 in the 0-5 fm depth range (Fig. 4, 5, 6). In August, a similar pattern exists, except the fishery moves to slightly deeper waters and is spread throughout the entire coast. We used 1979 to portray the offshore fishery; it probably depicts a typical year in Louisiana as its production of 27 million pounds was near the 15-year average.

Texas Fishery

The offshore fishery in Texas during June 1979 obviously was conducted outside the territorial sea of Texas, because it has been illegal since 1960 to fish inside 3 marine leagues at that time of year. Major production in June 1979 occurred in statistical subarea 21 in depth zones from 11 to 25 fm. The fishery in July 1979 was predominantly in the southern portion of the state, with major production occurring in subareas 20 and 21 in depth zones from 11 to 20 fm. Some production occurred in 16-30 fm; peak production occurred in 6-10 fm in subarea 18, with more or less uniform production in statistical subareas 20 and 21 (Fig. 7, 8, 9). The specific location of peak fishing off Texas varies between years; however, peak production usually occurs in statistical subarea 19 between 11 and 25 fm.

Size Composition 1972, 1977-80

For the past several years, small shrimp (68 count) have dominated the size composition in statistical subareas 13-17 in June (Fig. 10). Usually over 70 percent of the shrimp are 51 count or smaller. In July, the size distribution of shrimp off Louisiana increases to large-size animals. In some years there are two modes: One at size count category 31-40 and another at 51-67. In general, however, at least 60 percent of the brown shrimp catch is composed of shrimp smaller than 41 count/pound. By August, the catch is predominantly 31-40 count shrimp. There is some variation between years, with an occa-

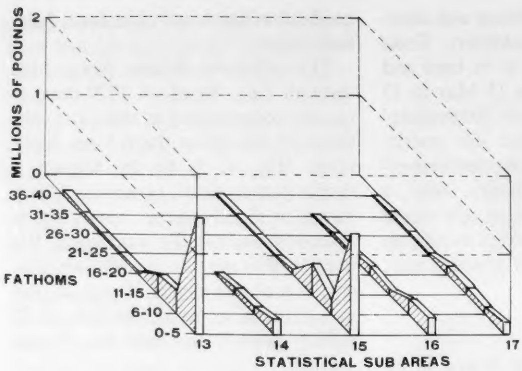

Figure 4.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Louisiana, June 1979.

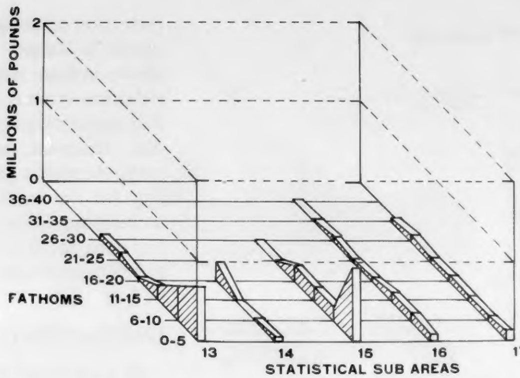

Figure 5.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Louisiana, July 1979.

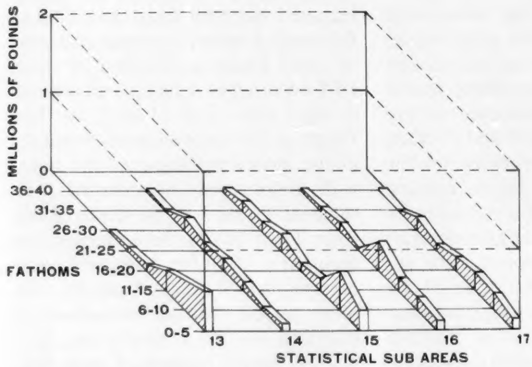

Figure 6.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Louisiana, August 1979.

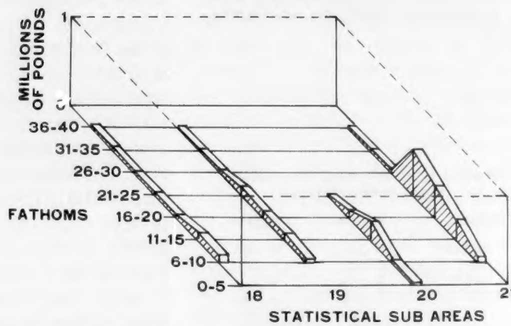

Figure 7.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Texas, June 1979.

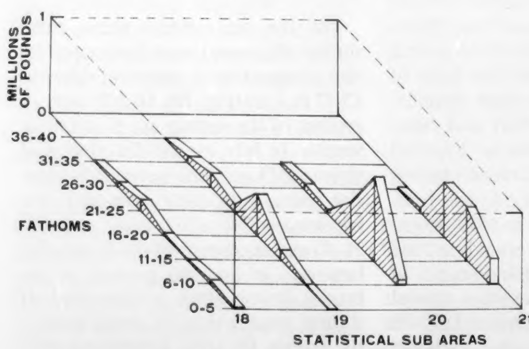

Figure 8.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Texas, July 1979.

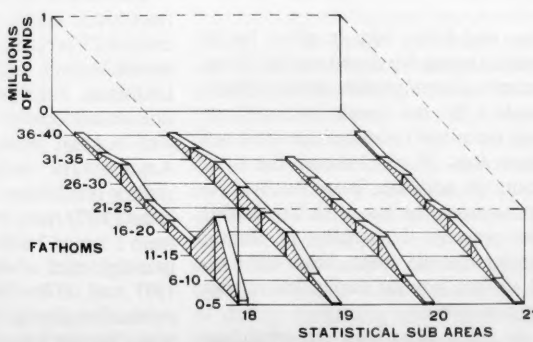

Figure 9.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Texas, August 1979.

sional dominant mode at 51-67 count/pound. However, the general trend for the majority of the catch is in the 31-40 size category.

Off Texas, the percent size composition in June varied considerably between years (Fig. 11). However, the dominant mode is 51-67 count shrimp with usually more than 40 percent of the shrimp comprising this or a smaller size of shrimp. However, one should recall that fishing is not permitted inside 3 marine leagues during June in Texas; therefore, the fleet is prohibited from capturing small shrimp as they immediately egress from the bay systems. Size composition of the commercial landings of brown shrimp in July varies considerably between years. Depending on the year, two peaks in the 61-67 and 31-40 size categories are apparent. In years of high landings, such as 1972 and 1977, there is a definite peak in the 31-40 size category in July. In years of low landings, such as 1980 and 1979, there is a peak in the 51-67 size category. In general, there is considerable variation between years in the size composition landed during July. The size composition in August off Texas is dominated by 31-40 count shrimp.

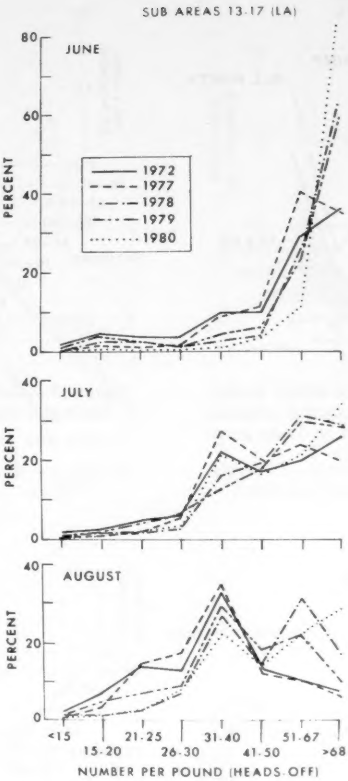

Figure 10.—Percent size composition of brown shrimp landings off Louisiana, June-August 1972, 1977-80.

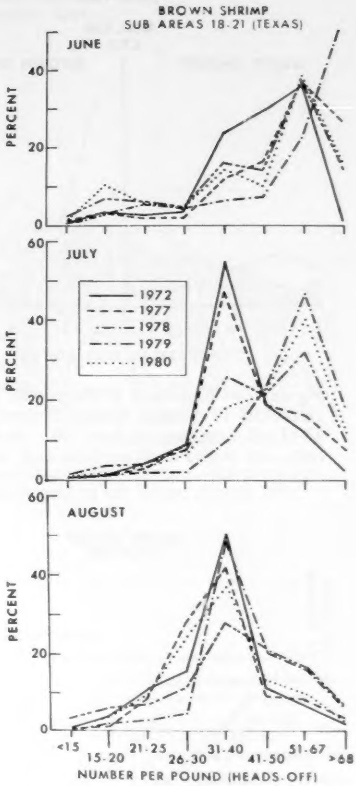

Figure 11.—Percent size composition of brown shrimp landings off Texas, June-August 1972, 1977-80.

The 1981 Fishery

In 1981, the FCZ and the territorial sea of the State of Texas were closed to all shrimp fishing from 22 May to 15 July. A daytime fishery from the beach to 4 fm was permitted along the entire Texas coast during this period. The total landed catch in June for the daytime fishery was approximately 28,000 pounds and 4,600 pounds of white and brown shrimp, respectively. The July white shrimp catch was 325,000 pounds. Over 90 percent of the catch was produced in statistical subareas 18 and 19. Since only 182 trips were made in Texas waters in June 1981, the major portion of the Texas fleet apparently did not fish in Texas waters. There were reports of occasional illegal fishing within the zone and approximately seven vessels were cited for infractions.

Louisiana

In June 1981 some Texas vessels fished in statistical subareas 17-14 in Louisiana (Fig. 12). The majority of vessels that landed in Texas fished for brown and white shrimp in statistical subarea 17 with over 1.6 million pounds of brown shrimp being produced from that subarea. Also, slightly more than 0.3 million pounds of brown shrimp were produced in subarea 16 and less than 0.1 million pounds were produced in subareas 14 and 15.

Texas vessels made 1,013 fishing trips to these subareas in June 1981. In addition to fishing for brown shrimp at night in statistical subarea 17, these boats also fished for white shrimp in the daytime in the 0-5 fm depth range. White shrimp averaged 21-25 count/pound, whereas brown shrimp averaged 51 count/pound or smaller. Over 67 percent of brown and white shrimp from subarea 17 and 32 percent from subarea 16 were landed in Texas ports. The remaining portion of the Louisiana coast was fished predominantly by Louisiana fishermen.

The brown shrimp fishery off Louisiana in June was concentrated basically in three statistical areas: 13, 15, and 17 (Fig. 13). Excepting subarea 17, the catch was produced from the 0-5 fm depth range with very little produced beyond that range. In subarea 17, the

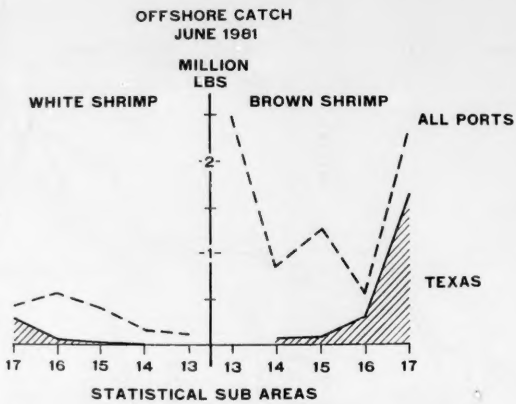

Figure 12.—Weights of offshore white and brown shrimp catches (in 10^6 pounds, heads-off) from statistical subareas 13-17 off Louisiana in June 1981, landed at Texas ports only, and landed at all northern Gulf ports.

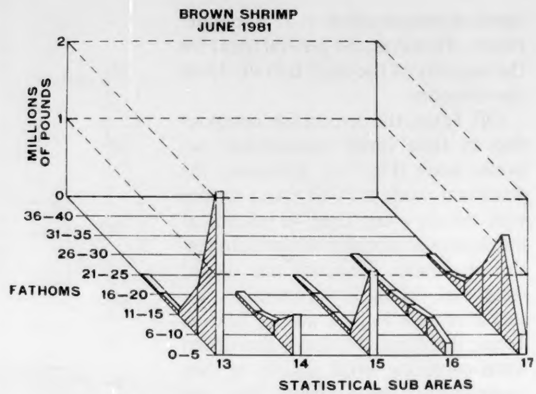

Figure 13.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Louisiana, June 1981.

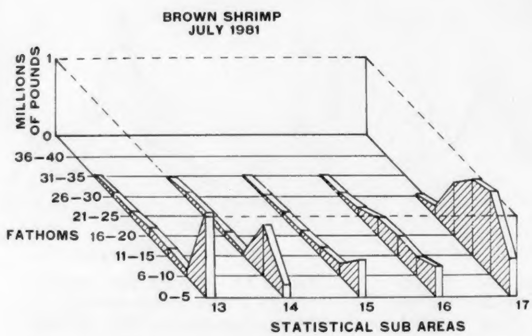

Figure 14.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Louisiana, July 1981.

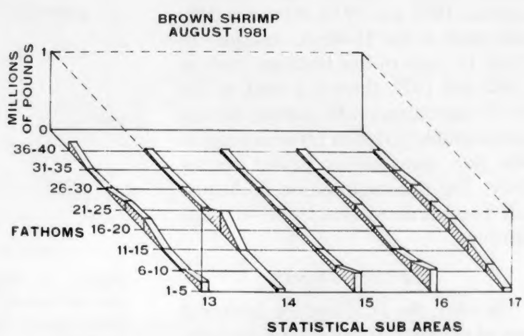

Figure 15.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Louisiana, August 1981.

majority of the catch came from the 6-10 fm depth range with an appreciable amount being produced in 11-15 fm. The majority of the catch landed in statistical subarea 17 was produced by vessels landing in Texas (Fig. 12). The July catch off Louisiana was approximately in the same geographical subarea and same magnitude as the June catch (7.5 and 7.4 million pounds in June and July, respectively). The major producing subareas were 13, 16, and 17. In subarea 17, production was over 3 million pounds with 80 percent being caught in the 6-20 fm depth range (Fig. 14). In contrast, subarea 13 produced 1.5 million pounds of which 67 percent was caught within 5 fm. The catch off Louisiana in August was extremely low, resulting in approximately 2.9 million pounds being landed. The catch was distributed more or less equally throughout the area, with no one subarea predominating (Fig. 15).

Texas

The July brown shrimp catch off Texas amounted to 10.3 million pounds and was produced in all subareas of the coast, with the major production occurring in statistical subarea 19 from the 11-20 fm depth range (Fig. 16). The catch was predominantly more offshore than that recorded for Louisiana and was significantly greater than the Louisiana production of 7.4 million pounds. About 80 percent of the Texas catch was produced in the 6-20 fm depth range and over 90 percent between 6 and 25 fm.

Approximately 14.6 million pounds of brown shrimp were caught in August off Texas, and this catch was distributed similarly to the July catch ex-

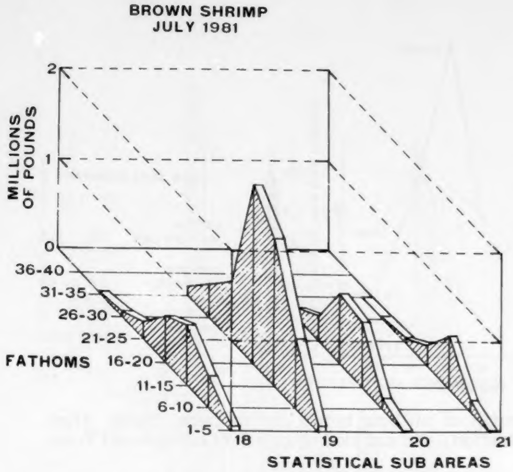

Figure 16.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Texas, July 1981.

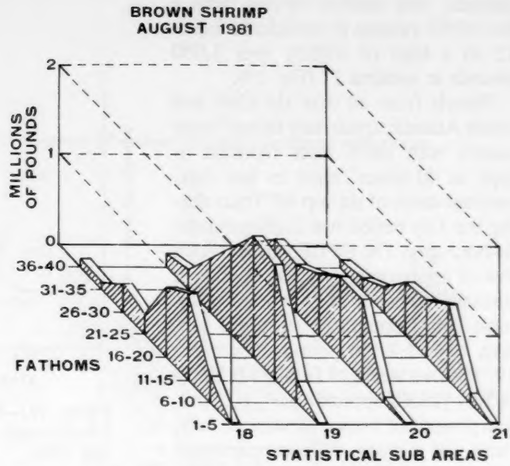

Figure 17.—Relationship of offshore brown shrimp catch to depth and statistical subarea off Texas, August 1981.

cept that more was produced farther offshore than in July. About 59 percent of the catch was caught between 11 and 20 fm and 75 percent from 11 to 25 fm. All subareas produced large quantities of shrimp, with subarea 19 being the largest production zone off Texas (Fig. 17).

The large production of shrimp in July resulted in some serious gluts of shrimp at the dock, with large concentrations of landings occurring in the third and fourth weeks of July. In Texas, shrimp are normally headed at sea. Immediately after the opening of the closed season, however, many of the shrimp boats were unable to head their entire catch and either discarded a portion of the catch or landed the catch heads-on. Since the processing industry was not prepared to process the large quantity of heads-on shrimp landed in July and August in Texas, some problems were encountered. To alleviate this problem, some of the shrimp landed in Texas were shipped to other ports in the Gulf area for processing.

During the first week of the open season, large catches were made offshore, and it has been reported to NMFS Southeast Fisheries Center port agents that there was some discarding of shrimp all along the coast due to the inability to handle the large catches with the normal 3-4 man crew. Discarding lasted only a couple of days, and thereafter adequate crews were placed aboard the vessels to handle the larger catches.

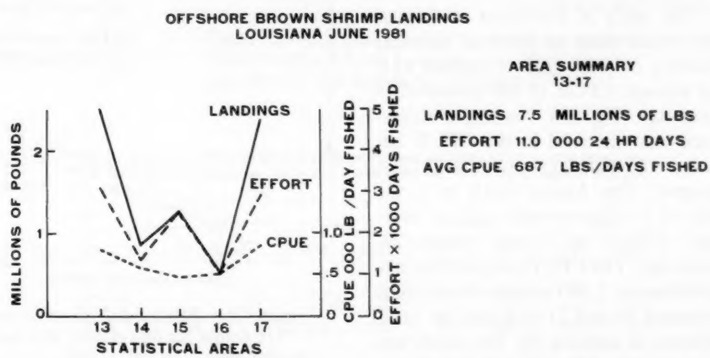

Figure 18.—Relationship of offshore brown shrimp catch, fishing effort, CPUE (catch per unit effort), and statistical subarea off Louisiana, June 1981.

Relative Abundance

In June, the Louisiana offshore catch was approximately 7.5 million pounds with approximately 11,000 24-hour days of fishing effort expended. The CPUE was 687 pounds/24-hour day with little variation between statistical subareas 13 and 17 (Fig. 18). The July catch and catch rates off Louisiana were similar to the June figures, although fishing effort was somewhat lower in July. The average catch in July off Louisiana was 858

pounds, with catches varying from a low of 641 pounds in statistical subarea 15 to a high of slightly over 1,000 pounds in subarea 17 (Fig. 19).

Vessels from all over the Gulf and south Atlantic apparently fished Texas waters with catch rates reported as high as 40 boxes[2]/night in late July. Average catch of shrimp off Texas during the July period was 2,250 pounds/24-hour-day. The CPUE varied from a low of approximately 1,900 pounds in statistical subarea 21 to a high of almost 2,400 pounds in statistical subarea 20 and 2,300 pounds in subarea 19. The two weeks of fishing off Texas in July yielded approximately 10.3 million pounds of brown shrimp. In July, there was a major difference between Texas and Louisiana brown shrimp production as well as the very large difference in the CPUE or relative abundance of brown shrimp. Relative abundance off Texas was almost 2.5 times greater than that experienced in Louisiana.

The catch in Louisiana in August was lower than in previous months, yielding only 2.9 million pounds with an average CPUE of 820 pounds/24-hour-day (Fig. 20). No major difference was observed in the CPUE between statistical subareas 13 and 17 in August. The August catch in Texas was 14.6 million pounds with an average CPUE of 1,346 pounds/24-hour-day. The CPUE ranged from approximately 1,100 pounds in statistical subareas 18 and 21 to a high of 1,600 pounds in subarea 20. The catch was remarkably different between Texas and Louisiana. The low catch in Louisiana contrasted with the high catch in Texas and may be attributed to a lower amount of fishing effort — only 3,500 days fished in Louisiana compared with 10,800 days fished off Texas. However, the real difference observed was a CPUE 1.6 times larger in Texas compared with Louisiana in August.

In comparing the June-August Louisiana catch between 1977 and 1981, it is evident that the catches in 1977, 1978, and 1981 were very similar, with slightly higher production in 1977 and

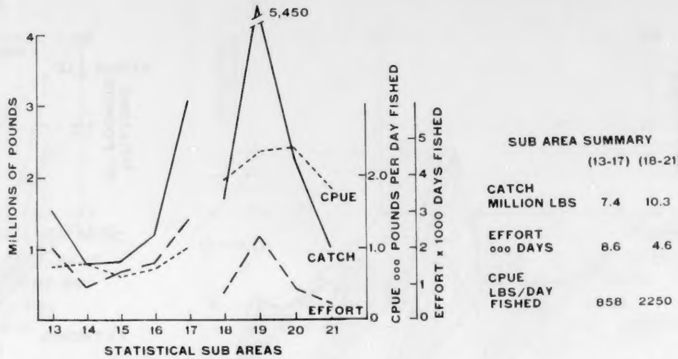

Figure 19.—Relationship of offshore brown shrimp catch, fishing effort, CPUE (catch per unit effort), and statistical subarea off Louisiana and Texas, July 1981.

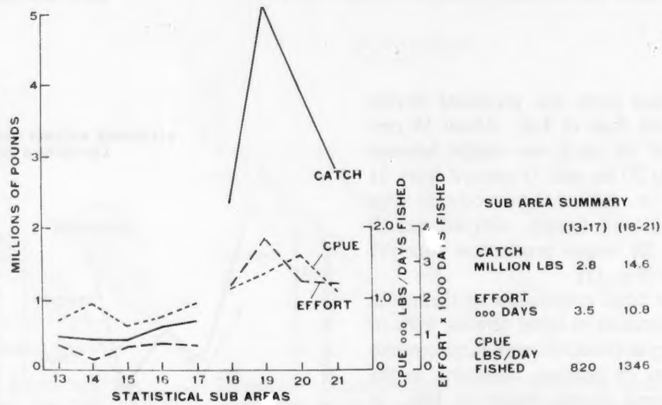

Figure 20.—Relationship of offshore brown shrimp catch, fishing effort, CPUE (catch per unit effort), and statistical subarea off Louisiana and Texas, August 1981.

1978 than in 1981. The notable difference between 1981 and 1977-78 was a 50 percent lower catch in August 1981 as compared with August 1977 and 1978. The catch in 1979 and 1980 in Louisiana was significantly lower than that for the three other years mentioned. In comparing the catches off the Texas coast in statistical subareas 18-21 for the June-August period, it is evident that the total July-August production in 1981 far exceeded the June-August production from 1977 to the present time as well as the June-August production in 1972, a very good brown shrimp year (Fig. 21).

In comparing the CPUE or relative abundance in statistical subareas 13-17 between 1977 and 1981, it is apparent that the relative abundance in June through August was somewhat similar in 1977, 1978, and 1981 (Fig. 22, Table 3). Average CPUE was 788 pounds/24-hour-day in 1981. In comparing the CPUE for statistical subareas 18-21 off Texas, again it is apparent that the

[2]Defined as 100 pounds heads-off shrimp.

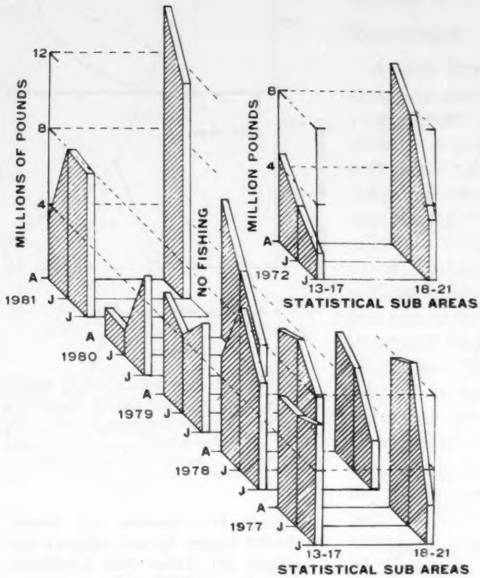

Figure 21.—Comparison of total offshore brown shrimp catches off the Louisiana and Texas coast in June (J), July (J), and August (A) 1972 and 1977-81.

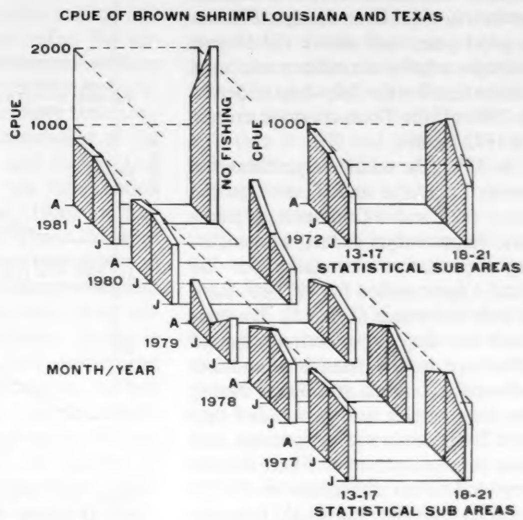

Figure 22.—Comparison of CPUE (catch per unit effort) of brown shrimp off the Louisiana and Texas coast in June (J), July (J), and August (A) 1972 and 1977-81.

relative abundance was significantly greater in July and August 1981 than in any of the previous years examined. Further, it is evident that the 1981 CPUE or relative abundance was much greater off Texas for the 3 months examined compared with the CPUE off Louisiana in 1981.

In addition, we have compared the same catch and relative abundance for a good year, identified as 1972, with 1981. The relative abundance in subareas 13-17 in 1972 was 820 pounds/24-hour-day compared with 788 pounds in 1981 — virtually no difference. Although relative abundance was approximately the same, the total catch in 1972 in this area was 8.8 million pounds compared with 17.7 million pounds in 1981. This large difference in production was due to a low level of fishing effort expended in 1972 compared with 1981 (Table 3). Off Texas in statistical subareas 18-21, the

Table 3.—Summary of brown shrimp catch (millions of pounds), effort (× 1000 days), and CPUE for Louisiana subareas 13-17 and Texas subareas 18-21, June-August 1972 and 1977-1981.

Year and item	June		July		August		Total	
	13-17	18-21	13-17	18-21	13-17	18-21	13-17	18-21
1972								
Landings	1.3	3.1	2.9	7.9	4.6	9.5	8.8	20.5
Effort	2.1	4.1	3.3	7.4	4.8	9.5	10.2	21.0
CPUE	640	771	872	1,073	948	997	820	947
1977								
Landings	6.4	2.1	5.8	8.6	5.9	8.0	18.1	18.7
Effort	7.4	2.9	6.3	7.5	6.1	8.9	19.8	19.3
CPUE	877	729	938	1,136	982	901	932	922
1978								
Landings	5.6	2.6	8.5	5.4	5.1	6.3	19.2	14.3
Effort	7.8	3.8	9.0	5.5	7.0	8.5	23.8	17.8
CPUE	721	675	941	988	733	742	798	801
1979								
Landings	5.7	1.9	4.2	3.9	5.3	3.5	15.2	9.3
Effort	9.8	3.2	14.8	5.5	9.6	6.4	34.2	15.1
CPUE	584	596	281	701	555	544	473	614
1980								
Landings	4.7	[1]1.4	1.5	4.6	1.8	7.2	7.9	13.2
Effort	6.2	3.5	1.6	6.8	2.1	6.7	9.9	17.0
CPUE	751	400	893	669	849	1,067	831	721
1981								
Landings	7.5	—	7.4	10.3	2.9	14.6	17.8	24.9
Effort	11.0	—	8.6	4.6	3.5	10.8	23.1	15.4
CPUE	687	—	858	2,250	820	1,346	788	1,798

[1]Interview data only.

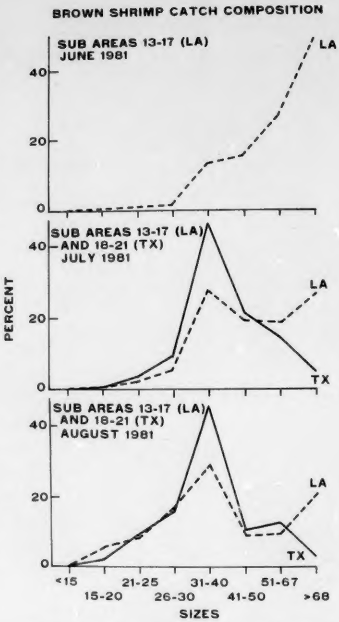

Figure 23.—Percent size composition of brown shrimp catches in June 1981 off Louisiana and in July-August 1981 off Texas and Louisiana.

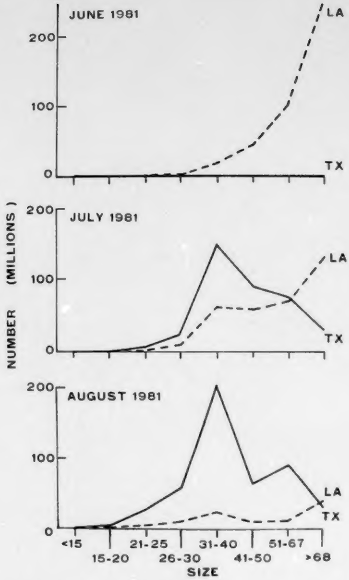

Figure 24.—Number of brown shrimp landed by size category and caught off Texas and Louisiana, June-August 1981.

relative abundance in 1972 was approximately 947 pounds/24-hour-day compared with an average of approximately 1,800 pounds in 1981. Total production in 1972 was 20.5 million pounds compared with 24.9 million pounds in 1981. Even though 1972 was a good year, well above the 15-year average, relative abundance and total production for the July-August period in 1981 off the Texas coast far exceeded 1972 figures.

In 1972, the relative abundance between Louisiana and Texas was the same (820 and 947 pounds/24-hour-day, respectively); in fact, in comparing the relative abundance for the June-August period for 1977-80, there is little difference (Table 3). We conclude that there is not normally a great difference in the relative abundance between Louisiana and Texas during the June-August time period and that the CPUE's reflect good, average, and poor shrimp production. There may be large individual differences in CPUE between specific statistical subareas and/or months; however, the average CPUE for the June-August period between Texas and Louisiana does provide a good measure of abundance for the entire area.

A large difference in the CPUE for the June-August period between Louisiana and Texas has not been observed from the data set we examined, except in 1981. The difference in the CPUE between Texas and Louisiana in 1981 may reflect an increase in survival of shrimp because of a decrease of fishing mortality of the 1981 brown shrimp year-class off Texas. However, we caution a conservative interpretation until additional future years replicate the 1981 CPUE information.

Size Composition

In 1981, over 70 percent of the Louisiana brown shrimp catch in June was composed of 51 count/pound or smaller size shrimp (Fig. 12). The July catch was dominated by two modal groups, 31-40 and 68 count/pound or smaller shrimp (29 percent and 28 percent, respectively). Average size composition of the landings in August consisted of 28 percent 31-40 count and 20 percent 68-count/pound or smaller shrimp.

In June, no fishing was permitted in statistical subareas 18-21 off Texas, but in July the brown shrimp catch was dominated by a single group of shrimp (31-40 count), which accounted for more than 45 percent of the entire catch (Fig. 23). The catch in August was also dominated by 31-40 count shrimp. Major differences were observed between Texas and Louisiana size compositions in July and, to some degree, in August. In general, the overall size composition of the Louisiana shrimp landed was smaller than of the shrimp landed in Texas (Table 4) in both months.

Table 4.—Percent size composition of 41-count or smaller brown shrimp landings, July and August 1981[1].

Month	Texas	Louisiana
July	41	63
August	27	39

[1]Shrimp statistics, Gulf of Mexico monthly landings, Technical and Information Management Services, NMFS, Southeast Fisheries Center, Miami, Fla.

Of particular interest are both the pounds as well as the number of shrimp caught. To estimate this, the count/size category and pounds landed were used to convert pounds into approximate numbers per size category. Although this is a crude measurement, it does provide some indication of the number of shrimp caught by size category and an approximate total per month. These data, plotted in Figure 24, indicate that a preponderance of small shrimp were caught in Louisiana in June and July. Further,

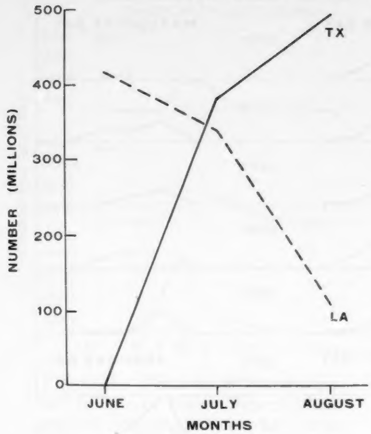

Figure 25.—Comparison of number of brown shrimp caught off Texas and off Louisiana, June-August 1981.

Figure 24 clearly indicates that larger size shrimp were landed in Texas in July and August.

Data on the total number of shrimp caught during the June-August period indicate Louisiana (subareas 13 and 17) produced 868 million shrimp whereas Texas (subareas 18-21), in comparison, produced over 876 million shrimp (Fig. 25). Even though the approximate numbers of shrimp taken in Texas and Louisiana were the same, Texas landings were composed of larger shrimp, presumably because of the closed season, and were correspondingly more valuable—$62.9 million for Texas vs. $35.6 million for Louisiana.

In summary, there was a major difference in July and August 1981 brown shrimp size composition between Texas and Louisiana, with larger shrimp landed in Texas than in Louisiana. Recent landings dating back to 1972 indicate that during good brown shrimp years, the 31-40 size category dominates the landings for both July and August in Texas but not necessarily in Louisiana. Landings in Texas in July 1981 are very similar to those in 1972 and 1977, both good brown shrimp years. The Louisiana shrimp size distribution in July and August 1981 was similar to that indicated by landings in 1977.

Recruitment

A wide array of environmental and biological factors may affect the survival, growth, and subsequent offshore shrimp population. Unfortunately, only a few parameters have been scrutinized. Present understanding of the recruitment process and factors that affect survival are not fully understood. St. Amant et al. (1966) and Barrett and Gillespie (1975) have identified and related temperature and salinity as important factors affecting subsequent production. They showed a direct correlation between salinities during a particular season and subsequent shrimp production. However, the best relationship between a single parameter and brown shrimp catch in Louisiana appears to be the number of hours of water temperature below 20 °C after April 8 (Barrett and Ralph, 1977). The size of the nursery area appears to be controlled by the distribution of high saline water, and survival appears to be related to the amount of time water temperatures are above 20 °C during critical periods in the spring. Therefore, salinity above and below 19‰ in the upper portion of the bays may greatly expand or contract the shrimp nursery areas and possibly affect survival of juvenile shrimp.

The TPWD has been sampling with bar seines, 10-foot trawls, and 20-foot trawls in the major bay systems for the March-August period since implementation of the offshore closed season in 1960. Richard L. Benefield and C. E. Bryan (TPWD)[3] have provided us an information summary of the relative abundance of brown shrimp in Texas bays for this period. The 1981 indices of abundance indicate that, generally, recruitment was less than observed in most bay systems for years of good offshore brown shrimp production (1967, 1972, 1976, 1977). The major exception was greater abundance levels in the lower Laguna Madre in 1981 than in any other year (Fig. 26, 27, 28).

In 1979, the TPWD initiated random sampling of seven bay systems with a bar seine to sample juveniles, presumably a better measure of abundance than other sampling methods[4]. The 1981 data indicate that recruitment in Texas bays was far greater in 1981 than in 1979 and 1980. However, it should be pointed out that 1979 and 1980 were below-average brown shrimp production years.

The salinity distribution in 1981 in Galveston Bay was apparently ideal for shrimp growth and survival[5]. Temperatures above 20 °C were observed throughout the bay in April and May; such temperatures indicate survival should have been good. Further, the high salinity allowed a larger nursery area for shrimp than when salinities were low. This combination of high salinity and temperatures had not been observed previously in Galveston Bay. The 1967 environmental conditions most closely resemble 1981 conditions; however, 1981 salinities were higher than in 1967. Therefore, even though the Galveston Bay CPUE indices were average, it simply may mean the shrimp used a larger area and were not concentrated at times when temperatures and salinities were not optimal, and may indicate the sampling was not adequate to detect this change.

It appears that the abundance of juvenile shrimp in 1981, from the TPWD recruitment data, was either slightly below good year indices or approximately the same. We do not think there was any question that shrimp recruitment in 1981 was greater than in poor years such as 1979 and 1980.

The juvenile shrimp index (catch of brown bait shrimp/hour) in Galveston has been a very good prediction of the offshore catch of brown shrimp in Texas (Caillouet and Baxter, 1973).

[3]Bryan, C. E., Texas Parks and Wildlife Department, Austin, Tex., and Benefield, R. L., Texas Parks and Wildlife Department, Seabrook, Tex., pers. commun. 1981.

[4]Bryan, C. E., Texas Parks and Wildlife Department, Austin, Tex., pers. commun. 1981.

[5]Benefield, R. L., Texas Parks and Wildlife Department, Seabrook, Tex., pers. commun. 1981.

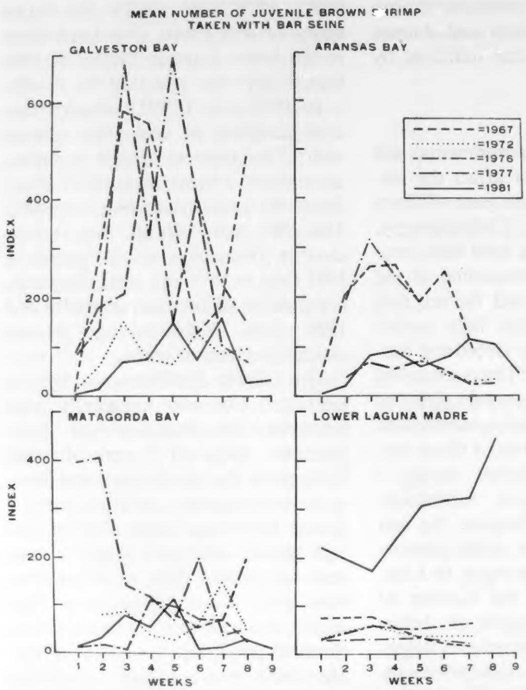

Figure 26.—Mean catch of juvenile brown shrimp taken with bar seines and 10-foot trawls during a 9-week period (March-August) 1967, 1972, 1976-77, and 1981 in four Texas bays (data from Benefield and Bryan, TPWD).

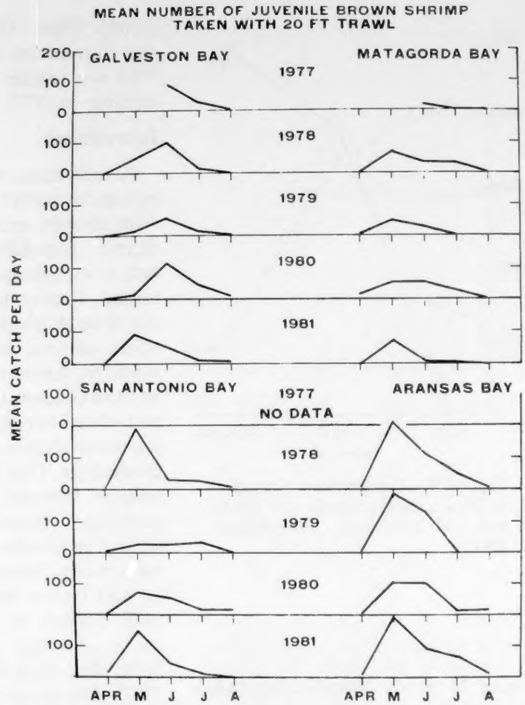

Figure 27.—Mean catch per day of juvenile brown shrimp taken with 20-foot trawls during April-August 1977-81 in four Texas bays (data from Benefield and Bryan, TPWD).

We have updated this model (R^2 = 0.86) to include 1960-74 data to predict the 1981 brown shrimp catch in Texas for the July-June period. The 1981 juvenile index predicts a catch of 28.8 million ± 5.7 million pounds at the 95 percent confidence level (Fig. 29). This index does not indicate a great inshore abundance level but rather an average level of abundance comparable to 1960 or 1963. Based on the 1981 recorded catch in July and August (24.5 million pounds) and production in September-November (12.0 million pounds) and an estimation of production in December-June (5 million pounds), our present best estimate of the July-June offshore brown shrimp catch is 40 million pounds, about 11 million pounds above the level predicted by our model. This difference is well above the upper 95 percent confidence limit, i.e., 34.1 million pounds, of the predicted catch, and we consider this difference to be significant. We assume the difference in the model's predicted value and the actual catch to be due to the Texas closure.

Discussion

The TPWD data indicated that recruitment of juvenile brown shrimp in Texas bays in 1981 appeared to be about the same level as during good brown shrimp production years (1967, 1972, 1976, 1977). We updated a model to predict the offshore brown shrimp catch based on an index of juvenile brown shrimp in Galveston Bay. This model has predicted the offshore catch remarkably well from 1960 to 1974. The production index in 1981 indicated average recruitment to offshore waters, very similar to TPWD indices of recruitment levels in 1981. The model indicated that the level of brown shrimp abundance in Galveston Bay was about average, but less than that of good years such as 1967 or 1972.

We conclude that there were average levels of juvenile shrimp abundance in Texas bays in 1981. Environmental conditions were adequate for good survival and growth, resulting in average to good shrimp recruitment to the offshore fishery, but there is no reason to believe that recruitment in 1981 was better than the outstanding years of 1967 and 1972.

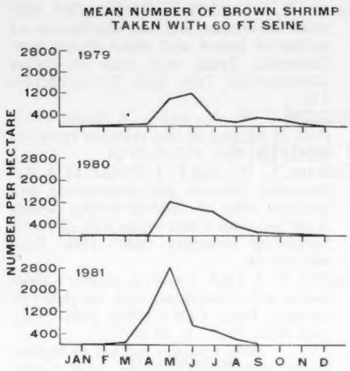

Figure 28.—Mean monthly numbers per hectare of brown shrimp taken with 60-foot bag seines in the Texas bays of Galveston, Matagorda, San Antonio, Aransas, Corpus Christi, and the upper and lower Laguna Madre, 1979-81 (data from Benefield and Bryan, TPWD).

The offshore abundance of brown shrimp in June and early July from survey data collected by the R/V *Oregon II* and *Western Gulf* indicates that the CPUE was extremely high for most of the Texas coastline[6]. In comparison with previous surveys, the CPUE was greater than any other historical data. However, we would like to point out that there is not a great wealth of historical information and, in fact, the surveys conducted this year by the *Western Gulf* and *Oregon II* were at higher sampling levels than were previous surveys. Abundance levels witnessed from the 1981 survey indicated that there would be a good shrimp crop along the entire Texas coast, with high concentrations in the 10-20 fm depth range. Furthermore, size distribution of the shrimp as observed from these surveys indicated

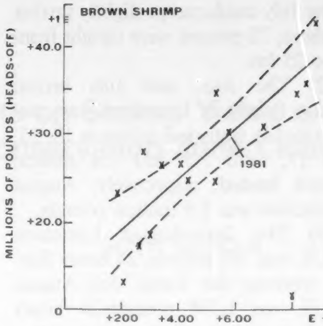

Figure 29.—Predicted annual offshore catches of brown shrimp in Texas 1960-74, and predicted brown shrimp catch July-June (1960-72 data from Caillouet and Baxter, 1973).

that shrimp in the 0-10 fm depth range were approximately the same size as from historical surveys. However, as we progressed to deeper water, the shrimp appeared to be slightly smaller than the historical survey data from 20 fm seaward.

The commercial fishery for brown shrimp began 16 July, with extremely high catches throughout subareas 18-21. In most areas, the CPUE was greater than 2,000 pounds/24-hours fishing during this period. The catch for both July and August was greater than that observed in any other like period off the Texas coast. Further, the catch off Louisiana appeared to be at a good level, with relative abundance levels almost reaching 900 pounds/24-hours fishing. Despite high abundance off Louisiana, many of the vessels in Louisiana diverted to fish in Texas where catch rates were higher. Similar to what we observed during good brown shrimp years, shrimp of 31-40 count size dominated the commercial catch off Texas in July and August 1981.

In reviewing all these data, the following is clear: 1) There was no fishing mortality on the brown shrimp stocks during June and the first 2 weeks in July; 2) size distribution of the offshore stock was similar to that observed during good brown shrimp years; 3) shrimp recruitment to the offshore fishery was average or slightly greater than average; 4) relative abundance, from survey data for the June-July 15 period off Texas, was greater than the historical CPUE's; 5) relative abundance for July-August off Texas was greater than the historical CPUE for the same period off Louisiana in 1981; and 6) the catch off Texas in July-August exceeded the brown shrimp catch for any other year.

Considering all these facts, it appears that the Texas closure did have a significant positive impact on increasing the relative abundance of shrimp as well as total production off the Texas coast.

Summary

1) Shrimping regulations and harvesting strategies vary from state to state along the Gulf coast. In Texas, regulations limit the landing of small shrimp, while in Louisiana there are few restrictions on the harvesting of small shrimp. As a result, the bulk of the Texas catch comes from an offshore brown shrimp fishery consisting of large shrimp, while in Louisiana, a substantial inshore fishery produces a large volume of small brown and white shrimp. Obviously, a higher overall value is realized from harvesting and marketing larger shrimp.

2) Historically, brown shrimp production from Louisiana inside waters is about 40 percent of the total production from May through July. The June-July Louisiana offshore fishery is usually concentrated in statistical subareas 13 and 15 within the 5 fm depth contour. Over 50 percent of Louisiana (subareas 13-17) brown shrimp annual production is produced from May through August. The average annual production from 1960 to 1980 was 24.7 million pounds.

3) In recent years, the specific location of peak production of the offshore Texas fishery varies in July-August between years but is usually concentrated in the 11-20 fm depth zone in statistical subareas 19, 20, and 21. Average annual production from 1960 to 1980 was 28.6 million pounds.

[6]Matthews, G. A., and S. L. Hollaway. 1981. A report on the distribution of *Penaeus* spp. along the Texas coast during the 1981 Texas closure (May-July). Report on file at Galveston Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Galveston, TX 77550.

Production of brown shrimp from inside waters in Texas since 1971 has been less than 9 percent of the total annual Texas catch.

4) The size distribution of brown shrimp landed in Louisiana in June is dominated by small shrimp, 68 count/pound. Shrimp size increases to large shrimp by July and usually to a 31-40 count by August. In July, the size of shrimp in Texas is usually larger than shrimp in Louisiana, but it does vary between years.

5) Texas waters and the Fishery Conservation Zone were closed to shrimp fishing from 22 May to 15 July 1981.

6) Texas-based vessels made 1,013 trips to Louisiana in June and caught about 2 million pounds of brown shrimp, mostly in statistical subarea 17.

7) In Texas, a daytime fishery was permitted inside 4 fm, which yielded 26,000 pounds of white shrimp and 4,600 pounds of brown shrimp in June 1981 and 325,000 pounds of white shrimp in July 1981.

8) Recruitment from Texas bays was considered similar to years of good brown shrimp production, but was not as good as 1967 or 1972.

9) The Texas July brown shrimp catch was 10.3 million pounds with major production from 11-20 fm in statistical subarea 19, but with good production along the entire coast.

10) The CPUE off Texas was significantly greater than the CPUE off Louisiana and greater than any other year from 1972 to the present off Texas and Louisiana.

11) The August brown shrimp catch was 14.6 million pounds and was caught in the same statistical subareas as the July catch except slightly farther offshore; 75 percent were caught from 11 to 25 fm.

12) The June and July brown shrimp fishery in Louisiana was concentrated in statistical subareas 13, 15, and 17, with 7.5 and 7.4 million pounds landed, respectively; August production was 2.9 million pounds.

13) The June-August Louisiana CPUE was 788 pounds/24 hours fished, whereas the Texas July-August CPUE was 1,798 pounds/24 hours fished.

14) During July and August, Texas landed larger shrimp than did Louisiana; the predominant size-count for shrimp off Texas in July and August was 31-40.

15) The predominant size of brown shrimp caught off Louisiana in June was 68 count or smaller; in July it was bimodal with peaks at 31-40 and 68 count or smaller.

16) The total number of shrimp landed from June to August in Louisiana was about the same as the total number of shrimp landed in Texas for July-August.

17) The Texas closure is believed to have had a positive impact on the relative abundance and production of brown shrimp off Texas during July and August 1981.

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Impacts on Shrimp Yields of the 1981 Fishery Conservation Zone Closure off Texas

SCOTT NICHOLS

Introduction

Between 22 May and 15 July 1981, trawl fishing was prohibited in the 200-mile Fishery Conservation Zone (FCZ) off the Texas coast. The FCZ was closed to implement part of the "Fishery Management Plan for the Shrimp Fishery in the Gulf of Mexico," developed by the Gulf of Mexico Fishery Management Council. The main purpose of the regulation was to improve yields by allowing newly recruited brown shrimp, *Penaeus aztecus* (Ives) to grow larger before harvesting.

Since 1959, Texas state waters (the Territorial Sea, 0-9 n.mi. from the coast) have been closed 45-60 days every year during the May-July period. In 1981, the FCZ off Texas was closed for the first time. In this paper I examine the effects of the Texas FCZ closure on yields of brown shrimp from the Texas FCZ area and on yields in offshore waters from the Gulfwide brown shrimp stock. The analytical facets presented are:

1) The size structure of the population in the FCZ, as deduced from a research cruise by the *Oregon II*,

2) A yield-per-recruit analysis for the Texas FCZ area, using population-structure data from the *Oregon II* cruise, and growth and mortality information derived by Parrack[1],

3) A virtual population analysis of the brown shrimp stock for May-August 1981, and

4) A simulation of Gulfwide fishing patterns and resulting yields that would have been expected in 1981 had the FCZ been open.

Additionally, descriptions of patterns of fishing effort, catch per unit effort (CPUE), and CPUE-derived estimates of stock distribution are presented in a discussion relating FCZ closure and Gulfwide yields.

Size Structure in the FCZ

The *Oregon II* conducted a trawl survey off the Texas coast, from 6 June until 2 July 1981, to estimate the size composition of the shrimp population in the FCZ. Data from cruises by the *Gus III* during the 1960's were used to identify major sources of variation for shrimp abundance and size composition. Knowledge of the variations allowed the development of a sampling strategy to maximize the precision of the estimates of the population's size composition. The *Gus III* data showed a strong relationship between shrimp mean size and depth, with a weaker relationship between CPUE and depth. Day/night differences in CPUE were indicated. Large variations in CPUE alongshore were observed, but no variations useful to sampling design was detected. Variations in CPUE and size with calendar time were confounded with alongshore, depth, and time-of-day variations in the complete data set. Examination of subsets of the data suggested that any relationships between average size or CPUE and calendar time were weak and probably varied from year to year.

The strategy employed was to sample in detail along the depth gradient. Sampling would be conducted as close to the end of the closure period as possible and be restricted to less than 3 weeks duration to minimize calendar time effects. All sampling would be done at night. One hundred samples were believed possible with these restrictions. Variations alongshore were assumed to be random. Economy of operation required that samples be taken in nonrandom order, eliminating any possibility of isolating calendar time effects and time × alongshore interactions. Operation of the *Oregon II* is limited to depths exceeding 5 fathoms (fm).

The Texas coast was stratified by 1-fm increments (except for two deeper strata of 30-35 and 35-50 fm). The number of samples in each stratum

ABSTRACT — A yield-per-recruit analysis and a simulation model of shrimp fishing show that an increase in brown shrimp yield was realized from closure of the Fishery Conservation Zone (FCZ) off Texas during May-July 1981. Yields were 11.7 million pounds greater (29 percent) than would have been expected with the FCZ open during May-August 1981. Some of the increase in yield was made at the expense of standing stock. Projections over the fishable lifespan of the shrimp indicate that yields will be increased 4 million pounds (7 percent) due to the FCZ closure.

[1]Parrack, M. L. Some aspects of brown shrimp exploitation in the northern Gulf of Mexico. Presented at the Workshop on Scientific Basis for the Management of Penaeid Shrimp. Key West, Fla., November 1981. Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, FL 33149.

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was allocated based on variances of CPUE from the *Gus III* data and spatial area in each stratum. Each sample was taken by trawling across the entire width of its stratum in the direction of maximum depth gradient (40-foot shrimp trawl, 8-foot by 40-inch wood door). To avoid overloading the net and reducing CPUE, trawls were raised after 30 minutes, emptied, and trawling resumed for those samples where stratum "width" exceeded 30-minutes trawling time.

Sampling for the size distribution study took place between 6 June and 28 June. Problems in operations prevented sampling the 35-50 fm strata as designed. Three nonrandom, nighttime samples taken for other purposes (two on 1 July) were available and were treated as if they were random samples. Apparent low abundances outside 35 fm probably minimize negative impacts from this substitution. Because shrimp CPUE's proved to be high, haphazard subsampling of trawl hauls was instituted during operations.

All shrimp caught were counted by species. Subsampled shrimp were sexed and measured for total length, and total lengths were converted to tail lengths using Brunenmeister's (1980) conversions.

The fraction of the population in any sex and size category was estimated using a ratio estimator:

$$P_i = \frac{\sum_{k=1}^{K}\left(\sum_{j=1}^{J_k} \frac{A_k}{J_k}\, a_{jk}\right)\left(\sum_{j=1}^{J_k} n_{ijk}\right)}{\sum_{k=1}^{K}\left(\sum_{j=1}^{J_k} \frac{A_k}{J_k}\, a_{jk}\right)\left(\sum_{j=1}^{J_k} N_{jk}\right)}$$

where P_i = fraction of the population in the ith sex and size class,

K = number of depth strata,

J_k = number of samples in the kth stratum,

A_k = fractional area of the kth stratum,

a_{jk} = length of the jth trawl in the kth stratum (a random variable in this formulation),

n_{ijk} = number of shrimp in size class i in the jth trawl in the kth stratum, and

N_{jk} = number of shrimp in all sex and size classes in the ith trawl in the kth stratum.

Estimated size and sex composition in the FCZ, treating the cruise as if it were synoptic, is shown in Figure 1. Using these data, the age composition of the population at the beginning of the closure period was estimated. By assuming that the mortality rate and growth rates derived by Parrack (footnote 1) hold, and ignoring migration, the population structure in the FCZ was projected back to 22 May 1981 (Fig. 2).

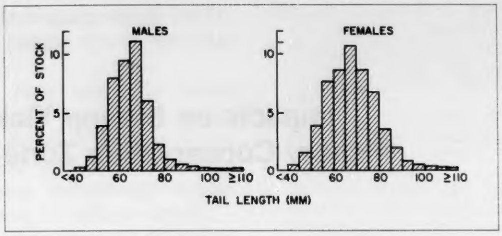

Figure 1.—Population size and sex structure of brown shrimp in the Texas FCZ, 6-28 June 1981.

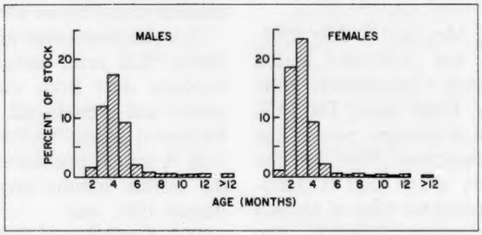

Figure 2.—Projected age and sex structure of brown shrimp in the Texas FCZ, 22 May 1981.

Yield-Per-Recruit Analysis for the Texas FCZ

Effects within the FCZ of allowing fishing vs. closure in the Texas FCZ were examined using a yield-per-recruit type model, substituting the population structure of 22 May for "recruitment." Effects of growth, natural mortality, and fishing mortality were simulated using a weekly time step. Reliable, age-specific estimates of fishing mortality rate (F) for the Texas FCZ alone are not available, so results are presented as a function of F. (An approximate value of F for the entire Texas area will be derived in a succeeding section and its implications discussed at that point.) Migration across the boundaries of the Texas FCZ was assumed to be zero during the closed period. As a practical matter, this implies that all shrimp detected in the

FCZ during the cruise were present throughout the closed period and that no shrimp entered the Texas FCZ after the cruise. I believe the effects of this simplification are minor, causing if anything an overestimate of any gain due to closure.

The simulation showed that the standing stock (by weight) in the Texas FCZ should have increased 78 percent during the closed period. Translating the stock increase into yield depends on the intensity of fishing. Closure of the Texas FCZ will produce increased yield at all but exceedingly low *F*'s (Fig. 3). Assuming that closing the FCZ only delayed fishing, and that fishing intensity would be the same whenever the area opened, the gain in potential yield from the FCZ can be estimated as a function of *F* (Fig. 4). Empirical evidence presented in the next section actually indicates that *F* following closure exceeded the level expected had the FCZ been open. Thus, if *F* following closure exceeded about 0.6, then the expected gain in yield per recruit would be less than is shown in Figure 4.

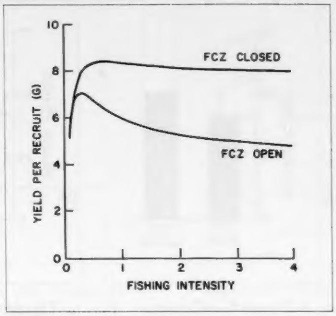

Figure 3.—Estimated yield of brown shrimp per recruit from the Texas FCZ.

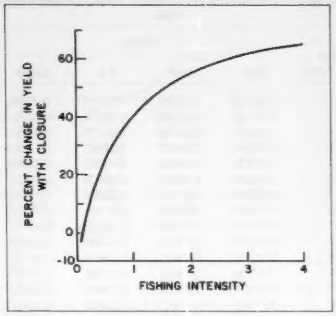

Figure 4.—Estimated percent gain in yield of brown shrimp per recruit from the Texas FCZ with closure.

Table 1.—Estimated catch of brown shrimp (in thousands) by age, May-August 1981.

Age (mo)	Month of capture			
	May	June	July	August
3	90,611.4	84,313.3	46,352.0	21,796.3
4	173,120.0	236,579.8	255,452.5	169,250.8
5	116,955.1	171,197.7	249,326.9	197,776.7
6	18,466.8	68,552.2	158,533.1	134,647.5
7	7,799.5	24,614.0	80,989.0	83,684.6
8	3,941.3	10,957.5	44,385.2	53,248.4
9	1,913.4	5,301.6	22,137.9	26,965.1
10	921.0	2,611.5	11,951.7	14,961.8
11	594.5	1,653.2	7.650.5	9,861.3
12	349.4	741.7	3,990.0	7,112.5
13	272.7	553.6	2,828.2	4,784.9
14	202.2	401.9	2,006.6	3,324.9
15	148.5	295.0	1,471.7	2,438.7
16	108.1	216.5	1,086.4	1,799.3
17	78.5	157.2	788.3	1,305.6
18	60.2	122.1	618.4	1,023.3
19	44.8	90.9	460.2	761.5
20	34.2	68.1	340.0	563.3
21	25.1	52.2	268.8	444.1
22	21.2	42.4	213.2	353.1
23	14.7	29.8	150.8	249.6
24	10.3	22.1	116.0	191.3
25	8.3	17.2	88.7	146.6
26	8.3	17.2	88.6	146.4
27	4.4	7.7	34.4	57.6

Table 2.—Estimated stock size of brown shrimp (in thousands) for May-August 1981.

Age (mo)	Month			
	May	June	July	August
3	1,194,219.0	928,643.7	489,185.3	257,554.0
4	936,692.7	939,069.7	717,460.0	376,152.4
5	538,154.7	642,605.0	586,402.6	379,731.8
6	251,825.4	353,128.8	392,749.2	273,487.4
7	152,505,8	198,612.8	239,239.5	190,852.6
8	102,823.2	123,402.9	147,381.4	130,446.9
9	77,896.2	84,417.6	95,567.0	85,391.2
10	45,843.7	64,943.2	67,399.7	61,453.8
11	29,955.0	38,410.1	53,205.4	46,702.9
12	20,905.5	25,104.5	31,367.5	38,508.3
13	15,039.5	17,580.8	20,814.5	23,181.9
14	10,967.2	12,628.1	14,545.0	15,216.5
15	8,367.6	9,205.6	10,443.5	10,605.2
16	6,319.7	7,028.9	7,611.3	7.586.2
17	4,673.6	5,312.4	5,819.6	5,516.2
18	3,753.4	3,930.0	4,404.4	4,256.6
19	2,704.9	3,158.9	3,252.8	3,201.5
20	2,072.3	2,275.0	2,621.3	2,361.3
21	1,620.3	1,743.1	1,885.5	1,931.2
22	1,189.3	1,364.4	1,444.6	1,366.8
23	750.8	998.9	1,129.3	1,040.4
24	377.1	629.4	828.0	828.0
25	164.9	313.5	518.6	602.1
26	78.3	133.6	252.6	362.4
27	42.1	59.4	98.5	134.9

Virtual Population Analysis of the Offshore Brown Shrimp Stock

Estimates of brown shrimp landings by market size category for the U.S. Gulf of Mexico from January through August 1981 were obtained through the statistical collection program of the Southeast Fisheries Center's Technical and Information Management Service. The procedures used in Parrack's analysis (footnote 2) of the brown shrimp fishery for 1960-79 were followed to determine brown shrimp effort and to estimate the age composition of the landings from market-size categories. Estimates of landings by age for May-August 1981 are presented in Table 1.

A virtual population analysis (VPA) of the landings was performed using the age data in Table 1 (see Ricker, 1975, for a general description of the method). VPA requires that the catch-by-age table be complete and accurate, that the natural mortaility rate *(M)* be known, and that the fishing mortality rate *(F)* be known for at least one time period in the life of each cohort. Although discarding and unreported landings are certain to have occurred, Table 1 is treated as if it were complete. The possible effects of unreported catches are considered in the discussion. Parrack's estimate (footnote 1) of $M = 0.155$ per month was used. Estimates of age-specific *F*'s were made for August based on August fishing effort, the distribution of the stock in August as inferred from CPUE, and past observed relationships between *F*, fishing effort, and CPUE-derived stock distribution patterns from Parrack's work.

Stock size estimates for the May-August period are presented in Table 2; fishing mortality rate estimates are given in Table 3. Compared with Parrack's stock size estimates for previous years, 1981 appears to be a particularly strong year. Abundances of shrimp recruited during the spring and early summer of 1981 are roughly on a par

Table 3.—Estimated brown shrimp F values for May-August 1981.

Age (mo)	Month			
	May	June	July	August
3	0.08536	0.10301	0.10775	0.09568
4	0.22182	0.31588	0.48125	0.65712
5	0.26631	0.33736	0.60775	0.81294
6	0.08238	0.23437	0.56667	0.74746
7	0.05675	0.14333	0.45150	0.63396
8	0.04224	0.10063	0.39078	0.57522
9	0.02686	0.07014	0.28654	0.41412
10	0.02192	0.04435	0.21183	0.30353
11	0.02165	0.04755	0.16829	0.25771
12	0.01820	0.03240	0.14740	0.22166
13	0.01976	0.03456	0.15827	0.25115
14	0.02009	0.03495	0.16090	0.26797
15	0.01934	0.03519	0.16464	0.28412
16	0.01864	0.03381	0.16695	0.29447
17	0.01829	0.03244	0.15774	0.29376
18	0.01746	0.03411	0.16398	0.29909
19	0.01805	0.03155	0.16533	0.29544
20	0.01797	0.03282	0.15051	0.29642
21	0.01689	0.03288	0.16671	0.28415
22	0.01938	0.03414	0.17315	0.32535
23	0.02138	0.03274	0.15537	0.29842
24	0.02978	0.03854	0.16358	0.28566
25	0.05583	0.06115	0.20352	0.30350
26	0.12118	0.14957	0.47211	0.56721
27	0.12000	0.15000	0.47000	0.61180

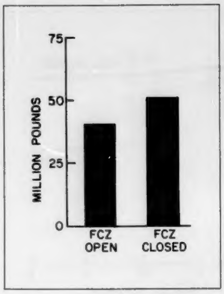

Figure 5.—Comparison of Gulfwide May-August 1981 yields of brown shrimp: FCZ open vs. FCZ closed.

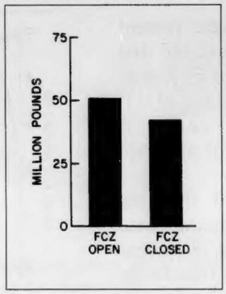

Figure 6.—Comparison of Gulfwide August 1981 standing stock of brown shrimp; FCZ open vs. FCZ closed.

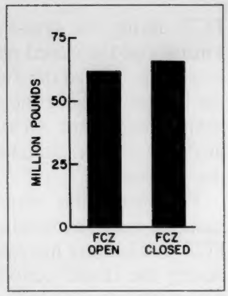

Figure 7.—Comparison of Gulfwide brown shrimp yields over the fishable lifetime of the "protected" shrimp: FCZ open vs. FCZ closed.

with 1978 levels. Abundances of older shrimp also appear to be high, as was the case in 1977. Fishing mortality rates for 1981 appear to be similar to 1977-78 levels.

Yields, Had the FCZ Been Open

Probably the most reasonable prediction of what fishing mortality rate would have been had the FCZ been open can be derived from age-specific *F*'s in recent years when the FCZ was open. I generated fishing mortality rate estimates using the average 1977-78 *F*'s calculated by Parrack (footnote 1) as a baseline fishing pattern. Data for these years are the most recent available and both represent "good years" for brown shrimp landings. To set the magnitude of the *F*'s for 1981, I assumed that effort expended in August indexed effort "available" for 1981, which was 62.3 percent of the average effort for 1977-78 in August. Fishing mortalities for May-August 1981, had the FCZ been open, were estimated to be 0.623 multiplied by the 1977-78 average levels.

Simulated fishing of the May-August period, using the May stock size estimates and May-July recruitment generated from the VPA analysis, provides estimates of Gulfwide yields obtainable had the FCZ been open. To project through the fishable lifespan of the shrimp present during the closure period, the 1977-78 rates multiplied by the August effort ratio were extended through December. The January-April fishery had changed radically in 1981 compared with 1977-78, in that effort was only 22 percent of the 1977-78 level. Assuming this represents a change in fuel price economics that will continue, winter fishing was simulated by multiplying the 1977-78 *F* level by 0.22. Because small contributions to yields can be expected for a second year, the *F*'s just described were repeated for a second year (May through April).

Closing the Texas FCZ appears to have increased Gulfwide yields in weight by 29 percent (11.7 million pounds of tails) during the May-August period (Fig. 5). Some increase was registered during the closure, not just after. Part of the short-term increased yields were achieved at the expense of the standing stock on the grounds. Existing Gulfwide biomass on 1 August was estimated to be 20 percent lower than predicted with the FCZ open (Fig. 6). Over the fishable lifespan of the shrimp present or recruited during closure, the gain in yield estimated from closing the Texas FCZ was 7 percent, about 4.1 million pounds Gulfwide (Fig. 7).

Discussion

The changes in yield estimated with the Gulfwide analysis can be reconciled very well with the predicted local changes in yield from the Texas FCZ. Examination of the expected gain stockwide and the patterns of fishing effort will indicate both an effect due to protection of a portion of the stock and an effect due to an alteration in fishing pattern. Some components of the effort pattern alteration can be clearly attributed to the closure.

Assuming there had been no changes in effort patterns, the maximum effect of closure on Gulfwide yields can be approximated. An estimation of *F* off Texas in August was made via Baranov's catch equation (Baranov, 1918, cited in Ricker, 1975) using the reported catch off Texas, and an estimate of the average August stock size off Texas. August stock size off Texas was estimated as the fractional amount of the stock off Texas determined from August CPUE data multiplied by the average Gulfwide stock size determined from the VPA

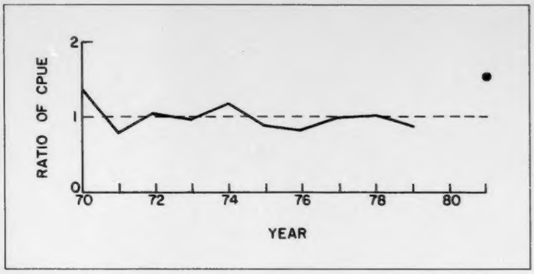

Figure 8.—Ratio of brown shrimp CPUE off Texas to CPUE elsewhere in the Gulf in August. Dashed line indicates the average value for 1970-79; dot is the 1981 value.

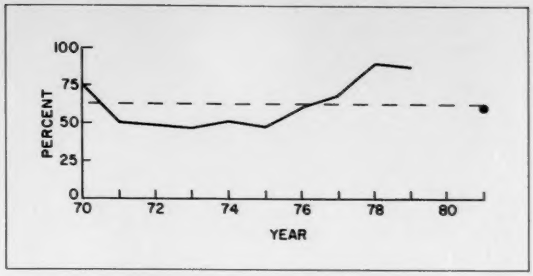

Figure 9.—Ratio of (brown shrimp directed) fishing effort in June vs. August, Gulfwide. Dashed line indicates the average value for 1970-79; dot is the 1981 value.

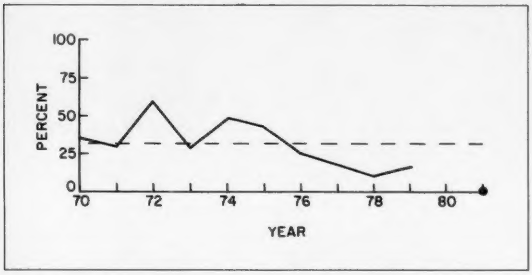

Figure 10.—Fraction of brown shrimp fishing effort off Texas in June. Dashed line indicates the average value for 1970-79; dot is the 1981 value.

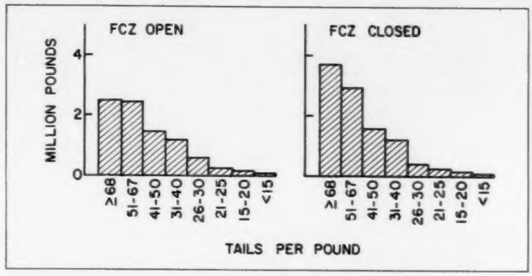

Figure 11.—Comparison of observed landings of brown shrimp by market size category in June 1981 (FCZ closed) with predicted landings (FCZ open).

analysis. Averaged over age, *F* off Texas was estimated to be 1.06 per month. Assuming this rate held for the Texas FCZ, the maximum gain from the FCZ is about 40 percent (from Figure 4). Projecting stock size estimates for Texas (using a "Texas only" VPA) to May, and calculating the percent of the stock off Texas actually in the FCZ from the *Oregon II* results, suggest that 29 percent of the Gulf stock was in the Texas FCZ at the time of closure. Enhancing yields from 29 percent of the stock by 40 percent implies that yields from the entire stock would be enhanced about 12 percent.

The high catch rates off Texas in 1981 relative to the rest of the Gulf apparently are due to the closure of the FCZ more than any unusual differences in recruitment between Texas and "elsewhere." Shown in Figure 8 are the ratios of CPUE off Texas vs. elsewhere, since 1970. The ratio averages about 1:1, with only 1970 even remotely approaching the ratio observed in 1981. If the ratio for 1981 had been 1:1 without closure, enhancement of the biomass in the FCZ by the predicted 78 percent would result in a ratio of catch rates of about 1.62:1 upon opening. This ratio agrees very closely with the 1.54:1 ratio observed in August.

Empirical comparisons of fishing effort patterns in 1981 with those of past years are inconclusive regarding a possible shift in effort from the Texas FCZ to other areas during the closed period. Shown in Figure 9 are the ratios of June effort to August effort, Gulfwide, for 1970-79 and 1981. The 1981 June:August effort ratio (61 percent) is very close to the 1970-79 average (63 percent). This suggests that almost all the effort traditionally exerted off Texas was relocated to other areas in the Gulf during the closure. On the other hand, the fraction of June effort off Texas had been declining in the late 1970's (Fig. 10), and the June:August ratio (Gulfwide, Fig. 9) had been rising. The average June: August ratio for the baseline years used in the yield simulation was 81 percent. The observed 1981 ratio of 61 percent suggests that more than the 15 percent Texas share of the effort for 1977-78 simply dropped out.

Comparison of the observed landings by size category in June 1981 with the size composition predicted for fishing with the FCZ open shows an increase in the smallest size categories and a slight decrease in larger sizes with FCZ closure (Fig. 11). A movement of effort from the more offshore areas of Texas to nearshore areas else-

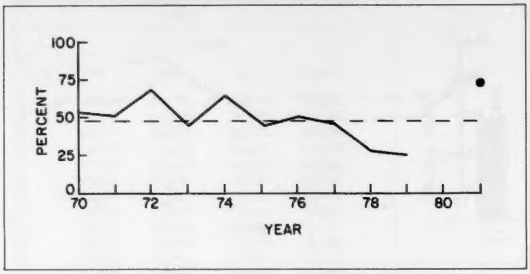

Figure 12.—Fraction of brown shrimp fishing effort off Texas in August. Dashed line indicates the average value for 1970-79; dot is the 1981 value.

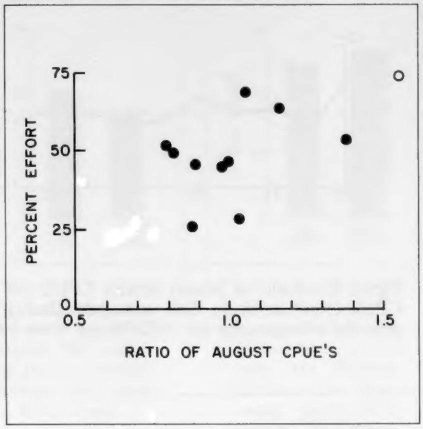

Figure 13.—Percent of Gulfwide brown shrimp fishing effort off Texas in August vs. ratio of August CPUE off Texas: August CPUE elsewhere in the Gulf, 1970-81. (Data unavailable for 1980.)

Table 4.—August catch per unit effort for brown shrimp off Texas and elsewhere in the Gulf, 1970-79 and 1981.

	Pounds of tails per 24-hours of fishing time[1]	
Year	Off Texas	Elsewhere
1970	1,041	757
1971	844	1,070
1972	933	891
1973	357	367
1974	685	591
1975	582	657
1976	648	797
1977	904	914
1978	747	727
1979	502	571
1981	1,289	832

[1]Brown shrimp directed.

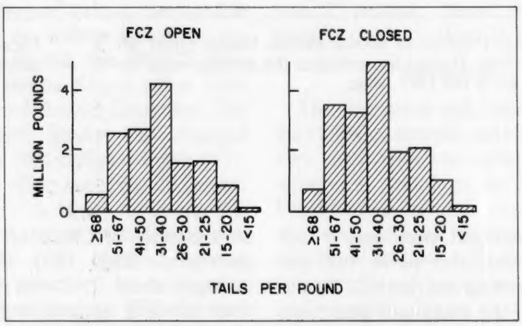

Figure 14.—Comparison of observed landings of brown shrimp by market size category in August 1981 (FCZ closed) with predicted landings (FCZ open).

where could help produce such a shift in size distribution of the catch, but because the existence of such an effort movement is uncertain, the existence fishing on smaller shrimp in June may not be directly related to the closure.

Whatever the extent of any effort movement during closure, there was apparently no large-scale depletion of the stock elsewhere in the Gulf. August CPUE for areas other than Texas are higher than all but three of the ten years, 1970-79 (Table 4). The approximate agreement between the observed ratio of August CPUE for Texas vs. elsewhere, and the ratio predicted simply from changes within the Texas FCZ, also suggest that no major depletion took place elsewhere.

Fishing effort comparisons do indicate a definite increase in effort off Texas relative to (and probably at the expense of) the rest of the Gulf after the closure ended. The fraction of August effort exerted off Texas since 1970 is shown in Fig. 12. The fraction for 1981 exceeds all previous years. The high catch rates off Texas undoubtedly attracted the large relative effort, although relative effort has been only weakly predictable from relative catch rates in the past (Fig. 13). Because most of the imbalance in catch rates appears to be due to the FCZ closure, the high relative effort off Texas can be directly attributed to the closure.

Comparisons of the catch by market size categories in August for the observed (FCZ closed) and simulated (FCZ open) conditions show an increase in all size categories, with virtually no change in average size landed (Fig. 14). The lack of change in

average size indicates that the change in fishing effort pattern in August in 1981 did not produce much change in the distribution of F among ages.

Sensitivity Considerations

I believe that there are three areas where consequences of particular assumptions and specific parameter estimates are potentially severe enough to require expanded discussion: 1) The natural mortality rate *(M)* estimate, 2) the "August multiplier" assumption for determining F had the FCZ been open, and 3) the effects of discarded or otherwise unreported catch.

Results of yield-per-recruit models are notoriously sensitive to departures of estimated M from the true value. If M is underestimated, the gains predicted for the FCZ could be overestimated. However, the predicted distribution of relative CPUE (Texas vs. elsewhere) was close to that observed. The predicted differences were based on the yield-per-recruit model, so any serious error in M is unlikely.

Establishing the magnitude of fishing mortality rates from the ratio of August effort in 1981 to the average effort in 1977-78 was chosen as the most straightforward procedure available. However, there is reason for concern in that the magnitude of the reduction in effort in 1981 relative to 1977-78 (62 percent) is not reflected in the fishing mortality rates for August. I believe this represents a real change in fishing patterns between 1977, 1978, and 1981. Much of the effort that dropped out may have been essentially "peripheral," in part perhaps the effort of less-efficient fishermen, but also due to reductions of effort in areas of relatively low stock densities. This change in fishing pattern calls into question the low multiplier, in that the effort, had the FCZ been open, might have been more "efficient" also. If fishing effort in 1981 was truly more "efficient," simulated F's might be too low, and that gain due to closure might be overestimated.

Any error caused by underestimating the value of F, had the FCZ been open, will overestimate the amount of yield gained due to closure, but there are three reasons why I believe the conclusion that there was some gain with closure is unaffected:

1) Some of the cause of the observed "high" F in August is legitimately due to intense fishing in areas of high stock densities, densities generated in part by the FCZ closure.

2) The F estimates for June on large shrimp are not out of line with the effort multiplier without postulating a change in "efficiency." (Smaller shrimp appear to have been exploited more "efficiently," however.)

3) The magnitude of the error in estimated F (had the FCZ been open) required to reverse the conclusion is rather high. F's with the FCZ open must be one-third higher than calculated to eliminate a predicted gain from closure. If F's were two-thirds higher, a net loss of less than 5 percent would have been predicted.

If discarding was a constant fraction of the landings for the FCZ, both open and closed, the effects of ignoring discards here would probably be minimal. The extent of discarding probably varies in a complex manner in response to relative abundances of small and large shrimp, total catch rates, and prices. I concluded that I could not predict changes in discarding practices and must ignore any effects. Qualitatively, the FCZ closure might be expected to reduce discarding, thus the gain from closure estimated here may be underestimated.

Conclusions

Closure of the Texas FCZ appears to have ample potential for increasing yields from the Texas FCZ, as indicated by the yield-per-recruit analysis. The empirical estimation of changes in Gulfwide yields indicated a gain slightly below that predicted simply from enhancement of Texas FCZ yields. Dilution of some of the gain would be expected if fishing effort patterns shifted out of the Texas FCZ during closure and into the FCZ after closure. A definite shift of effort to the Texas FCZ after opening is evident in the data. Evidence concerning possible shifts to other areas of the Gulf during closure is equivocal. Apparently, the closure did not cause any major depletion of brown shrimp throughout the rest of the Gulf.

The effects of the closure are superimposed on a fishery that has changed noticeably since the late 1970's, presumably in response to the economics of the times. The changes include a severe reduction of the winter brown shrimp fishery and an overall reduction in fishing effort, preferentially in areas of lower stock densities. Preferential reduction of effort in more marginal areas appears to have made the fishery more "efficient." Under 1981 conditions, potential gains from the closure were exploited more quickly than they would have been under late 1970's conditions, probably at some expense to yield benefits yet to be realized.

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Estimated Impacts on Ex-Vessel Brown Shrimp Prices and Value as a Result of the Texas Closure Regulation

JOHN R. POFFENBERGER

Introduction

Changes in commodity prices may result from any regulatory process that disrupts historical marketing conditions. The Federal regulation prohibiting offshore shrimp fishing during the time the State of Texas closes the territorial sea is anticipated to affect shrimp landings in Texas and therefore could be expected to affect ex-vessel or dockside prices. This paper presents estimates of the effects on shrimp prices as a result of changes in offshore landings due to the Texas closure regulation. Also, the change in ex-vessel value (or gross revenue) to the brown shrimp fishery resulting from the closure regulation is calculated.

Changes in prices caused by variations in the supply of shrimp are measured empirically by means of price flexibilities. Empirical estimates of price flexibilities provide the relative or percentage change in prices given a 1 percent change in the amount of shrimp landed. The data and analytical methodologies used to estimate price flexibilities of brown shrimp prices reported at ports in Texas and Louisiana are described in the Data Description and Methodology section. The Results section contains the estimated price flexibilities and provides comparisons of several alternative statistical models. Finally, the estimated changes in brown shrimp prices and landings are used to calculate the effect on gross revenue to this fishery.

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Data Description and Methodology

Price and Landings

In most published literature, shrimp prices are aggregated using a weighted-average price per pound. In this average (total value of landings divided by total amount landed), price per pound is weighted by the amount of different-size shrimp landed. The weighted-average price will therefore be determined not only by the price per pound, but also by the amount of the various sizes of shrimp in the landed catch.

Such weighted-average price data should be considered carefully for several reasons. First, shrimp are graded or sorted by size (i.e., number per pound) into eight marketing categories and the price per pound increases with the size of shrimp. For example, in May 1981, the reported price per pound was $5.63 for the largest-size category and $0.88 for the smallest-size category. The price of a single large shrimp was about $0.38 and that of a small one was slightly more than $0.01. Second, large landings in a few categories may skew the weighted average and camouflage movements in prices of other size categories. Third, the Texas closure regulation was implemented to increase the availability of larger, more valuable shrimp to the fishery.

Thus, the weighted-average (weighted over all sizes of shrimp) price per pound has the implicit assumption that the effects of the closure regulation would be spread equally over all size categories. For these reasons, the eight marketing categories were analyzed separately to determine the effects of the closure regulation.

Three species of commercially important shrimp—brown, pink, and white—are caught in the Gulf of Mexico off the coast of Texas and Louisiana. Due to its temporal and spatial distribution, however, brown shrimp, *Penaeus aztecus,* was the primary species affected by the closure regulation. Therefore, the analyses in this paper are restricted to brown shrimp prices.

The price and landings data used in the subsequent analyses are limited to monthly observations. This constraint is due to the manner in which landings were estimated in the simulation analysis performed by Nichols (1982). The constraints and feasibilities of using weekly price and landings data are discussed more thoroughly by Poffenberger[1]. The monthly time-series used in the regression analyses begin in January 1971 and continue through December 1980.

Methodology

The analysis presented in this paper was prepared after the closure and subsequent reopening of the offshore fishing areas; therefore, reported price and landings data from the brown shrimp fishery were available from

[1]Poffenberger, J. R. 1981. An analysis of price and value for the brown shrimp fishery in the Gulf of Mexico. Unpubl. rep., NMFS Southeast Fisheries Center, Miami, Fla., 45 p.

May through August 1981. To estimate the change in gross revenue, it is necessary to estimate the amount of landings that the fishery would reasonably have been expected to make during this 4-month period if the closure regulation had not been implemented. A simulation analysis provided estimates of the difference in brown shrimp landings if the area off the coast of Texas had been open for fishing during the early part of the brown shrimp season (Nichols, 1982). Changes in ex-vessel prices are determined by calculating the percentage difference between the monthly reported landings and the simulated landings. The percentage changes in landings are multiplied by the estimated price flexibilities and these products are multiplied by the reported prices for May through August.

The analysis that estimates the price flexibilities attempts to isolate only the effects of variations in U.S. domestic landings on brown shrimp prices, with the effects of other factors (such as imports and inventories) held constant. The statistical relationships between shrimp prices and landings were estimated by log-linear regression models (equations (1) and (2)). Using log transformations, the coefficients of the landings variables (L) in equations (1) and (2) provide the price flexibility estimates directly[2].

Two approaches were considered for statistically isolating the effects of shrimp landings on prices. First, a simple regression model was specified as follows:

$$ln(P_i) = ln(a) + b\,ln(L_i) + \varepsilon \quad (1)$$

where P_i = reported ex-vessel prices of the ith size category (i = 1, 2, . . ., 8);

L_i = the amount of brown shrimp landings at Texas and Louisiana ports for the same ith size category;

a = the intercept;

b = the estimated coefficient of the landings variable (in this model it is also the price flexibility estimate); and

ε = the random error.

The simple regression model in equation (1) was specified for two reasons. First, it was an attempt to estimate only the effects of landings on the respective prices. This model specification implies that the effects of all other factors would be captured in ε, the random error parameter. Second, this model was specified to help determine whether the effects of U.S. domestic landings on ex-vessel prices were dependent on the magnitude of the landed catches in different years. This hypothesis appears reasonable because of the large variations in catches which are affected by exogenous factors such as rainfall, salinity, and temperature. A more explicit description of this hypothesis is presented by Poffenberger (footnote 1).

The second approach was an attempt to statistically account for those factors that may dampen or reduce the effect of changes in landings on the price structure. For this case, a multiple regression model that includes the major influential variables was specified as follows:

$$ln(P_i) = b_1 ln(S) + b_2 ln(I) + b_3 ln(PPI) + b_4 ln(RCPS) + b_5 ln(L_i) + b_6 ln(OL_j) + \varepsilon \quad (2)$$

where P_i reported ex-vessel brown shrimp prices for the ith size category (i = 1, 2, . . ., 8),

S = the end-of-month cold storage holdings in total weight,

I = total pounds of foreign imports of fresh and frozen shrimp,

PPI = monthly producer price index for meat, poultry, and fish,

$RPCS$ = monthly per capita expenditures at eating and drinking establishments deflated by a subcomponent of the consumer price index,

L_i = the amount of brown shrimp landings for the ith size category,

OL_j = the amount of brown shrimp landings for the jth size category such that $j \neq i$,

a = the intercept,

b's = the estimated coefficients for the respective six independent variables, and

ε = the random error.

The specification for equation (2) is based largely on the model estimated by Chui (1980).

Results

When all 10 years of monthly data were used, the simple regression model as specified in equation (1) indicated a significant relationship between price and landings (i.e., $b \neq 0$) only for the <15 and >67 size categories (Table 1). Since these results did not provide the needed price flexibility estimates, simple regression models were estimated for individual years between 1971 and 1980. As suggested by the hypothesis that ex-vessel prices are more strongly influenced by domestic landings in years of large landings, the estimated coefficients were significantly different than zero for the models of 1972, 1976, and 1977. For brevity, only the regression results for these 3 years are presented in Table 1 (second, third, and fourth columns). Individual results for all 10 yearly models are provided by Poffenberger (footnote 1).

[2]The model specifications of equations (1) and (2) assume that the price flexibility estimates are constant over the range of the landings data. That is, the price flexibility estimates are the same at all locations of quantity supplied on the supply curve.

For the multiple regression model as specified in equation (2), data for the end-of-the-month cold storage holdings (S) and imports (I) are available only by total pounds in storage or imported, i.e., data on the amount of cold storage holdings or imports by size of shrimp are not available. Prices for the eight separate size categories of shrimp are regressed on the same data series for storage and imports, as well as on the producer price index (*PPI*) and real per capita spending (*RPCS*). Thus, only the landings data are different for the eight regressions (Table 2). The dominance of the producer price index (*PPI*) for all eight size categories suggests that the increasing pattern of shrimp prices over time may not allow the actual market (price-landings) relationships to be estimated. A comparison of historic monthly prices and landings also indicates that prices have a definite increasing trend, whereas monthly landings exhibit large fluctuations but do not appear to have either an increasing or decreasing trend. As examples, monthly price and landings data for the 21-25 and 41-50 size categories are graphed in Figures 1 and 2.

In an attempt to adjust for the effects of increasing trends in prices, the monthly ex-vessel prices were deflated by the producer price index for meat, poultry, and fish, and a multiple regression model similar to equation (2), but without the producer price index variable (*PPI*), was estimated using these data (Table 3). Comparing the results of the unadjusted model (Table 2) with the adjusted model (Table 3) indicates only two slight differences. First, the summary statistics of the adjusted model are lower than the statistics for the unadjusted model. This is due to the removal of the increasing trend in the price data and the strong relationship it had with the increasing nature of the *PPI*. Second, the magnitudes of the price flexibility estimates (the coefficients of the landings variables (L)) are slightly greater for the adjusted model relative to the unadjusted model.

The specifications of the adjusted

Table 1.—Estimated coefficients for simple regression models by size of shrimp[1].

Size class	1971-80			1972			1976			1977		
	ln(a)	b	R^2	ln(a)	b	R^2	ln(a)	b	R^2	ln(a)	b	R^2
<15	4.57	−0.30* (4.2)	0.13	1.05	−0.03 (0.3)	0.01	2.08	−0.06 (0.8)	0.05	0.84	−0.06 (1.1)	0.11
15-20	2.24	−0.09 (1.5)	0.02	1.66	−0.08 (1.4)	0.16	1.94	−0.05 (0.8)	0.07	3.56	−0.18* (3.4)	0.54
21-25	1.64	−0.05 (1.1)	0.01	1.66	−0.09* (5.2)	0.74	2.59	−0.10* (3.8)	0.59	2.96	−0.14* (10.3)	0.91
26-30	1.46	−0.04 (1.1)	0.01	1.45	−0.08* (4.7)	0.69	2.61	−0.11* (6.2)	0.79	2.45	−0.11* (5.0)	0.72
31-40	1.39	−0.05 (1.4)	0.02	0.88	−0.05* (7.0)	0.83	2.44	−0.11* (6.5)	0.81	2.23	−0.10* (4.9)	0.70
41-50	1.03	−0.04 (1.6)	0.02	0.49	−0.04* (3.2)	0.51	1.52	−0.07* (3.4)	0.53	1.29	−0.06* (6.2)	0.79
51-67	0.76	−0.04 (1.6)	0.02	0.52	−0.06* (3.9)	0.60	1.16	−0.05* (3.9)	0.45	1.15	−0.06* (7.6)	0.85
>67	0.13	−0.03* (2.2)	0.04	−0.32	−0.03 (1.5)	0.19	0.41	−0.04* (5.0)	0.71	0.42	−0.04* (3.1)	0.49

[1]The regression equation for the four models is specified in equation (1). In the first model, monthly data from January 1971 through December 1980 (120 observations) are used. In the other three models, monthly data for the respective years are used (12 observations for each model). R^2 is the coefficient of determination, and the respective values of the t-ratio are presented in parentheses below each coefficient. It should be noted that the value of the F-ratio for a simple regression equation is equal to the t-ratio squared. All price and landings data are from the Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, FL 33149.

*Indicates that the coefficient is significantly different from zero at $\alpha = 0.05$.

Table 2.—Estimated coefficients for the unadjusted multiple regression model by size of shrimp, 1971-1980[1].

Size class	ln(a) constant	Independent variables[2]						R^2	F-ratio	D-W
		L	S	I	PPI	RPCS	OL			
<15	−8.96	0.02 (0.4)	−0.03 (0.4)	0.28 (2.9)	1.34 (14.6)	0.53 (2.0)	−0.05 (2.2)	0.787	69.6	0.26
15-20	−7.58	−0.03 (0.6)	−0.13 (1.5)	0.33 (3.5)	1.28 (14.7)	0.57 (2.2)	−0.06 (2.3)	0.802	76.4	0 35
21-25	−7.17	−0.10 (4.8)	−0.15 (1.9)	0.30 (3.5)	1.34 (16.5)	0.48 (2.1)	—	0.826	108.3	0.43
26-30	−8.00	−0.04 (1.2)	−0.12 (1.5)	0.30 (3.3)	1.46 (17.2)	0.44 (1.7)	−0.06 (1.5)	0.843	100.9	0.43
31-40	−5.56	0.06 (1.4)	−0.39 (4.8)	0.18 (2.4)	1.34 (15.1)	1.17 (4.3)	−0.14 (4.9)	0.881	139.3	0.52
41-50	−5.53	−0.09 (5.9)	−0.37 (4.5)	0.11 (1.4)	1.54 (16.3)	0.77 (2.6)	—	0.870	152.5	0.37
51-67	−4.87	−0.11 (3.7)	−0.39 (4.3)	0.11 (1.3)	1.50 (15.6)	0.65 (2.2)	0.02 (0.8)	0.858	114.0	0.52
>67	−11.22	−0.5 (4.3)	0.01 (0.1)	0.00 (0.0)	1.76 (11.8)	0.91 (1.9)	—	0.749	67.9	1.06

[1]The regression equation for this model is specified in equation (2). The dependent variables are ex-vessel brown shrimp prices for the respective size classes, January 1971-December 1980 (120 observations). These price data are in current dollars and are not adjusted by any price index. The summary statistics are: R^2 = the coefficient of determination and respective values of the t-ratio are presented in parentheses below each coefficient; F-ratio and D-W = the Durbin-Watson statistic which measures the presence of first-order serial correlation.

[2]Independent variables are as follows:

- L = landings for each of the eight marketing categories;
- S = end-of-month cold storage holdings as reported by the National Marine Fisheries Service, Washington, D.C.;
- I = imports of fresh and frozen shrimp reported by the National Marine Fisheries Service, Washington, D.C.;
- *PPI* = producer price index (U.S. Bureau of Economic Analysis, 1972-1981);
- *RPCS* = per capita expenditure at eating and drinking establishments (U.S. Bureau of the Census, 1981) adjusted by a subcomponent of the consumer price index; and
- *OL* = landings of the following sizes of shrimp—for the <15 to 26-30 categories, the 21-25 landings were used as the *OL* variables; for the 31-40 to 51-67 categories, the 41-50 landings were used.

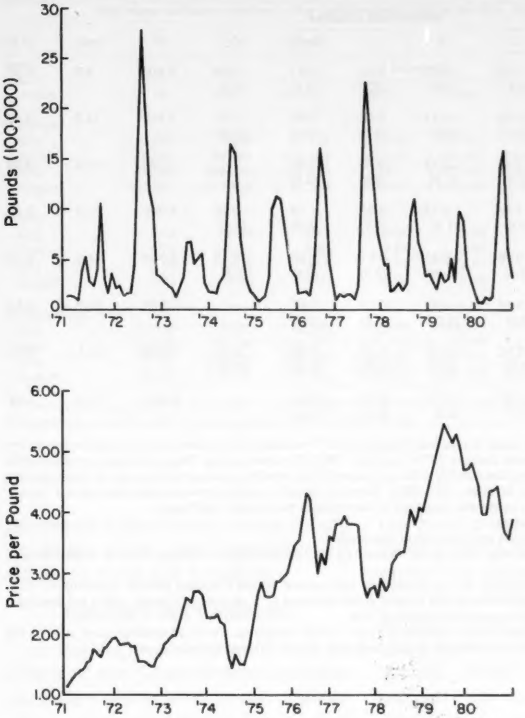

Figure 1.—Reported monthly landings (pounds) and ex-vessel prices of brown shrimp in the 21-25 size category landed at Texas and Louisiana ports, 1971-1980.

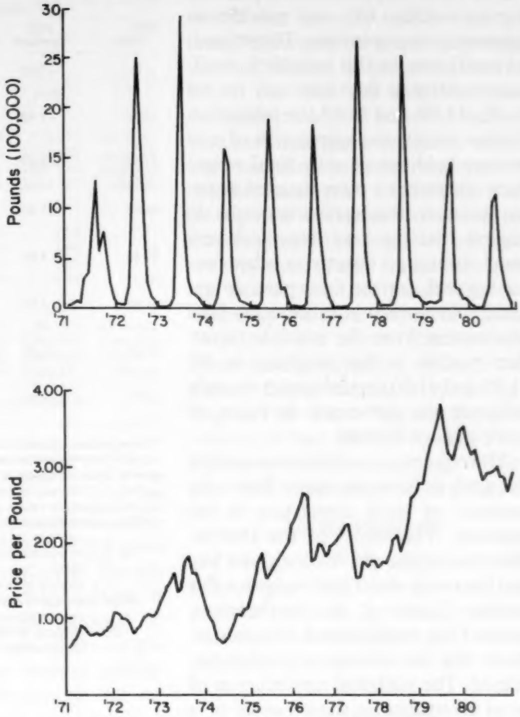

Figure 2.—Reported monthly landings (pounds) and ex-vessel prices of brown shrimp in the 41-50 size category landed at Texas and Louisiana ports, 1971-1980.

model also allow the hypothesis concerning the relationship between price and landings in good vs. average years to be tested. The 10 years of data were divided into two groups: Good years and average years. The data set for the good years contained the 36 observations of 1972, 1976, and 1977; whereas the data set for the 7 average years contained the remaining 84 observations. The estimated coefficients for the landings variable and their estimated standard errors were used to construct confidence intervals (at $\alpha = 0.05$) around the estimated coefficients. For all eight size categories, the confidence intervals for the good and average years have substantial overlap, indicating that the hypothesis should be rejected and therefore a difference between good and average years does not exist.

Discussion

Indirect evidence from the multiple regression models suggests the nature of the relationship between ex-vessel prices, size of shrimp, landings, storage, and imports (Tables 2, 3). The relationships between prices and landings for the two largest size categories are not statistically different than zero; however, the relationships between prices of these two categories and imports (I) are significant. The statistical relationship between prices and imports remains significantly different than zero for the size categories of <15 through 31-40 (i.e., large shrimp). These relationships suggest that predominately large shrimp comprise foreign imports into the United States. It is interesting to note that the signs of the estimated coefficients for imports (I) are positive, therefore suggesting that the amount of shrimp being imported reacts to ex-vessel prices rather than to prices being influenced by the amount of imports[3].

[3]Although the t-statistic for the import parameter is significant ($\alpha = 0.05$), two reasons strongly suggest that further research is required before a conclusion on the cause and effect between imports and ex-vessel prices can be accepted. First, the serial correlation present in these models may be causing the inappropriate significance of the import parameter. Second, these models may be misspecified as a single equation and a simultaneous model may be necessary to completely account for the interaction between imports and ex-vessel prices.

The other important variable, cold storage holdings (S), also provides an interesting interpretation. The estimated coefficient for this variable is significantly different than zero only for the 31-40, 41-50, and 51-67 size categories. Unfortunately, the aggregation of cold storage holdings data by total weight does not permit a more detailed analysis; however, the regression results do suggest that the very large and very small shrimp go directly to other processing and, for the most part, do not enter cold storage inventories. A final observation from the multiple regression models is that landings in the 21-25 and 41-50 size categories strongly influence the movement in prices of other sizes of shrimp.

The regression models estimated for this analysis have one major flaw—the presence of serial correlation in the residuals. The values of the Durbin-Watson statistic (D-W) are quite low and are not in the critical range for this statistic (Tables 2, 3). Furthermore, plots of the standardized residuals indicate that the residuals are highly correlated. The statistical consequence of serial correlation is the presence of a bias in the estimation of the variance of the stochastic disturbance term. Thus, while the estimated coefficients (least-squares estimators) are still consistent and unbiased, they no longer have a minimum variance, which means that the t-tests and F-tests are, in general, invalid. This problem raises some question regarding the validity of the statistical relationship between price and landings, but not necessarily the magnitude of the estimated coefficients.

Notwithstanding this problem, the estimated price flexibilities of landings for the eight size categories of shrimp are shown in Table 4. Asterisks indicate that the t-ratios for the respective coefficients are greater than the critical values for the t-distribution at an α = 0.05. The most important result of this comparison is the similarity in magnitude of the estimated price flexibilities irrespective of the model specification. Because absolute differences do exist in these estimates, however, the changes in prices calculated from the

Table 3.—Estimated coefficients for the adjusted multiple regression model by size of shrimp, 1971-1980[1].

Size class	ln(a) constant	Independent variables[2]							
		L	*S*	*I*	*RPCS*	*OL*	R^2	*F*-ratio	*D-W*
<15	−7.95	−0.02 (0.5)	−0.05 (0.6)	0.32 (3.3)	0.91 (3.5)	−0.05 (2.0)	0.260	8.0	0.31
15-20	−7.46	−0.00 (0.1)	−0.14 (1.5)	0.35 (3.6)	1.00 (4.3)	−0.08 (2.6)	0.348	12.2	0.40
21-25	−6.87	−0.10 (4.7)	−0.16 (1.8)	0.35 (3.8)	0.94 (4.5)	—	0.375	17.3	0.48
26-30	−7.30	−0.10 (2.6)	−0.15 (1.6)	0.32 (3.2)	1.19 (5.0)	−0.02 (0.4)	0.386	14.3	0.51
31-40	−4.96	0.08 (2.3)	−0.45 (5.4)	0.21 (2.7)	1.86 (8.5)	−0.19 (6.7)	0.600	34.2	0.73
41-50	−4.63	−0.13 (8.9)	−0.43 (4.7)	0.17 (1.9)	1.87 (7.3)	—	0.520	31.2	0.54
51-67	−3.91	−0.12 (4.0)	−0.47 (4.7)	0.16 (1.7)	1.68 (6.6)	0.00 (0.1)	0.489	21.8	0.62
>67	−8.97	−0.07 (6.7)	−0.14 (0.9)	0.00 (0.0)	2.41 (6.0)	—	0.344	15.1	0.89

[1]The regression equation for this model is specified in equation (2). The dependent variables are ex-vessel brown shrimp prices for the respective size classes, January 1971-December 1980 (120 observations). These price data are adjusted for general price increases by dividing the monthly price per pound by the monthly producer price index for meat, poultry, and fish (U.S. Bureau of Economic Analysis, 1972-1981). Summary statistics are the same as those described for Table 2, and the respective values of the t-ratios are presented in parentheses below each coefficient.

[2]Independent variables are as follows:

L = landings for each of the eight marketing categories;
S = end-of-month cold storage holdings as reported by the National Marine Fisheries Service, Washington, D.C.;
I = imports of fresh and frozen shrimp reported by the National Marine Fisheries Service, Washington, D.C.;
RPCS = per capita expenditure at eating and drinking establishments (U.S. Bureau of Census, 1981) adjusted by a subcomponent of the consumer price index; and
OL = landings of the following sizes of shrimp—for the <15-20 categories, the 21-25 landings were used as the *OL* variables; for the 31-40 through 51-67 categories, the 41-50 landings were used.

price flexibilities would also be different depending on the model.

The remaining task is to use the price flexibility estimates to calculate the estimated effects on ex-vessel prices and then determine the change in gross revenue to the fishery. Both the reported and simulated (Nichols, 1982) landings for May through August 1981 are presented in Table 5, along with the reported brown shrimp prices. These data are combined with the price flexibility estimates presented in Table 4 to calculate the estimated prices during this 4-month period had the offshore area been open to fishing. The gross revenue (based on reported ex-vessel prices and landings) of the brown shrimp fishery for May through August 1981 was about $119 million. Had the Texas closure regulation not been in effect, the fishermen would have received slightly higher prices for the shrimp, but would have caught about 11.7 million pounds fewer shrimp (Nichols, 1982). The estimated gross

Table 4.—Comparison of price flexibility estimates.

Size class	Single regression models		Unadjusted[2] model	Adjusted[2] model
	1971-80	Average[1]		
<15	−0.30*	N.S.	0.02	−0.02
15-20	−0.09	−0.18*	−0.03	−0.00
21-25	−0.05	−0.11*	−0.10*	−0.10*
26-30	−0.04	−0.10*	−0.04	−0.10*
31-40	−0.05	−0.09*	0.06	0.08*
41-50	−0.04	−0.06*	−0.09*	−0.13*
51-67	−0.04	−0.06*	−0.11*	−0.12*
>67	−0.03*	−0.04*	−0.05*	−0.07*

[1]Values in this column are the simple averages of the estimated coefficients from Table 1 that have a t-ratio greater than the critical value at α = 0.05.

[2]The unadjusted model includes price data in current dollars, whereas price data in the adjusted model are deflated by the producer price index for meat, poultry, and fish.

*Indicates t-ratios of these coefficients are greater than the critical value of a t-distribution for α = 0.05.

N.S. means none of the estimated coefficients were significantly greater than zero (α = 0.05).

revenue that the fishery would have received without the regulation is $97.6 million if the adjusted model is used or $97.4 million if the unadjusted model is used. Therefore, the difference or

Table 5.—Preliminary reported landings (in pounds), ex-vessel prices ($), and simulated landed catch (pounds) by size class for brown shrimp in the northwestern Gulf of Mexico, May-August 1981.

Item and month	Size class							
	< 15	15-20	21-25	26-30	31-40	41-50	51-67	>67
Landings[1]								
May	25,056	73,288	92,129	114,578	386,271	453,449	710,077	3,970,281
June	29,497	92,251	226,653	381,219	1,163,097	1,528,908	2,889,330	3,694,365
July	74,593	358,740	1,286,830	1,775,641	4,623,821	3,989,621	4,898,646	2,030,981
August	134,751	1,017,503	2,108,325	1,845,797	4,968,539	3,254,896	3,557,107	995,092
Prices[1]								
May	5.58	5.46	5.17	4.35	3.38	3.05	2.66	0.77
June	5.74	5.34	4.95	3.85	2.80	2.41	1.99	1.03
July	5.63	5.12	4.16	3.11	2.41	2.15	2.01	1.32
August	5.43	4.42	3.33	2.76	2.36	2.17	2.04	1.38
Simulated catch[2]								
May	74,636	155,560	175,196	188,282	380,915	332,831	467,315	2,288,193
June	34,609	121,709	242,777	531,426	1,113,768	1,416,483	2,457,639	2,492,539
July	28,427	182,832	699,639	1,181,032	3,392,978	3,210,926	4,047,937	1,644,817
August	72,445	810,562	1,597,439	1,589,093	4,288,949	2,650,516	2,549,840	720,592

[1]These NMFS data represent landed catch and ex-vessel prices reported at ports in Texas and Louisiana.
[2]Estimated by Nichols (1982) by a simulation cohort analysis model.

net benefit to the brown shrimp fishery resulting from the regulation is estimated to be $21.5 million.

Summary and Conclusion

In this paper, I have estimated the effects of the Texas closure regulation on shrimp prices and the concomitant effects on ex-vessel value of the Gulf of Mexico brown shrimp fishery. My methodology, described in the Data and Methodology section, was to estimate brown shrimp landings and prices under the assumption that the offshore area along the Texas coast was open to shrimp fishing as it has been historically. These estimates are compared with the actual reported landings and prices, and the difference represents a reasonable estimate of the closure regulation's effect on the gross revenue to shrimp producers. The use of brown shrimp landings caught in offshore areas limits the estimates of this analysis to the direct effects on this specific fishery. The analysis neither accounts for any impacts on the inshore fisheries in Texas and Louisiana nor does it account for any spillover effects on white or pink shrimp prices.

The Results section provided a detailed explanation of the two analytical approaches that were considered. In both approaches, the purpose was to estimate the statistical relationships between price and landings, with the influence of other factors being held constant. The hypothesis underlying the simple regression model, that assumed that ex-vessel prices were affected differently in good vs. average years of shrimp production, was rejected, and only the estimated price flexibilities from the adjusted and unadjusted multiple regression models were considered. Furthermore, when the estimated price flexibilities from the separate models are compared, the magnitudes of the empirical estimates are very close (Table 4) and the resulting estimates of ex-vessel value are essentially the same for either model. Therefore, the direct effect of the Texas closure regulation on the brown shrimp fishery during May through August 1981 was to increase the gross revenue of that fishery by about $21.5 million or slightly more than 18 percent of its reported ex-vessel value.

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Comparison of Shrimp and Finfish Catch Rates and Ratios for Texas and Louisiana

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Introduction

The Fishery Conservation Zone off Texas was closed to shrimp trawling from 22 May to 15 July 1981 to provide shrimp with an extended growing period in anticipation that they would be larger when harvested and bring a better market price. This closure coincided with a state-imposed closure from shore out to the Texas territorial boundary, closing the entire Texas coast to shrimping for 55 days.

To evaluate impacts of the Texas closure period, the National Marine Fisheries Service (NMFS) undertook a series of investigations, ranging from shrimp population dynamics to shrimp economics. Emphasis was on yield and catch-per-unit-effort statistics; however, attention also was given to effects of the closure on finfish bycatch from the shrimp fleet. This paper presents results from this latter effort along with applicable findings related to the shrimp fishery.

Previous investigations into shrimp fleet bycatch in the Gulf of Mexico include Gunter (1936) in Barataria Bay and adjacent Gulf waters; Blomo and Nichols (1974) in the western Gulf; and Bryan and Cody[1], Chittenden and McEachran (1976), and Bryan (1980) off the Texas coast. Only three of the papers provide estimates of finfish/shrimp catch ratios. Bryan and Cody (footnote 1) sampled the brown shrimp fleet off Texas from June 1973 to June 1975 and reported on overall finfish/shrimp ratio of 2.0 (heads-on). Chittenden and McEachran (1976) studied bycatch on both white and brown shrimp grounds off Texas from September 1973 to June 1974 and reported an overall fish-to-headed-shrimp ratio of 10.0 (approximately 6.0 heads-on ratio). Bryan (1980) found finfish/shrimp ratios ranged from 1.1 to 3.6 (heads-on shrimp) on the Texas brown shrimp grounds in 1973-74.

Methods

Contemporary Data

Observers trained by NMFS were on board cooperative commercial shrimping vessels in 1981 to document shrimp and bycatch catches following the Texas closure. Texas closure data collected in 1981 were compared with similar observer data collected in 1980 off Texas and Louisiana during a sea turtle incidental catch and mortality study. During both studies, observers recorded total shrimp (heads-on weight) and live catch for each tow. The first successful tow of each day was further sampled for bycatch analysis. A 40-50 pound sample of the bycatch was taken and individual species were counted and weighed. Additional samples were collected if the vessel moved to a new area during the day or a change occurred in the gross appearance of the bycatch. Sampling procedures for both years were the same with allowances made only for weather

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[1]Bryan, C. E., and T. J. Cody. 1975. Discarding of shrimp and associated organisms on the Texas Brown shrimp (*Penaeus aztecus* Ives) grounds. Tex. Parks. Wildl. Dep., unpubl. rep.

ABSTRACT — A comparison was made between 1980 and 1981 commercial fishing to judge effects of the 1981 Texas closure on shrimp and finfish catches off Texas and Louisiana. Historical data (1973-78) for the two areas were used as baselines, and comparisons were made of finfish/shrimp catch ratios and species composition. Mean shrimp catch rates (heads-on) standardized to 100-foot trawls for Texas and Louisiana in 1980 were 42.56 pounds/hour and 42.53 pounds/hour, respectively, and in 1981 were 89.03 pounds/hour and 62.20 pounds/hour. Mean finfish catch rates for Texas and Louisiana in 1980 were 333.90 pounds/hour and 242.84 pounds/hour, respectively, and in 1981 were 156.19 pounds/hour and 408.88 pounds/hour. Average finfish/shrimp ratios for Texas were 12.94 in 1980 and 2.55 in 1981. For Louisiana, the average finfish/shrimp ratios were 22.15 in 1980 and 37.23 in 1981.

Differences between 1980 and 1981 shrimp catch rates off Texas and Louisiana, and between Texas and Louisiana in 1981, were significant at the 95 percent confidence level. Finfish catch rates off both states were significantly influenced by depth, with no significant differences found between years for either state when the effect of depth was removed. Species composition of the bycatch in waters 10 fathoms or less was relatively consistent regardless of state or year. The composition of bycatch from deeper waters was much more variable and significantly different from catches made in the shallower waters. Overall, the analyses supported a hypothesis of increased shrimp catch rates due to the Texas closure. Finfish catch rates and compositions, however, were not shown to change as a result of the closure. This latter conclusion assumes the distribution of fishing effort by depth zone was unaffectd by the closure.

conditions, nature of the vessel, or restrictions imposed by the vessel captain. Total catch weights were obtained through direct measurement or by a weight-calibrated volumetric technique (i.e., number of baskets of known weight). Net type and size, vessel characteristics, fishing location, date, fishing time, and bottom type also were recorded.

Historical Data

Historical data consisted of data collected during 1973-78 by the NMFS Shrimp Fleet Bycatch Program at the Southeast Fisheries Center's Pascagoula Laboratory. Data were acquired with random trawl tows from research vessels and by contractual arrangements with several state agencies. For the latter, observers were placed on board commercial shrimp vessels for direct sampling of the catches.

Only selected data from resource assessment surveys conducted from fisheries research vessels *Oregon II* and *George M. Bowers* were used in the analyses (selection method described in Pellegrin, Drummond, and Ford, in prep.). Samples equal to at least 10 percent of the total catch were taken from each station with a commercial concentration of shrimp. They were sorted by species, with each species being weighed and number of individuals counted. Additionally, data were collected concerning date, depth, fishing location, time, minutes fished, and gear type.

Data Analysis

Catch rates of various net sizes and types were standardized to 1-hour tows and 100-feet of headrope. This was accomplished by dividing the catch weight by total headrope length and hours fished, and multiplying the result by 100. The 100-foot standard was selected for convenience of calculation and not due to any relationship to the average trawl size used on the shrimp grounds. This form of standardization is not ideal, as it assumes catch is proportional to headrope length and time fished. Errors that arise from this assumption, however, should be relatively minor as long as the size of the nets used is not too different from the 100-foot standard. In any case, finfish/shrimp ratios and catch composition should be relatively unaffected by the standardization.

Data summaries and statistical tests were performed with untransformed data. Catch data frequently follow skewed distributions, and common practice is to use logarithmic transformations to normalize the distributions. To insure that analytical conclusions were not significantly affected by the skewed distributions, all analyses were also performed with logarithmically transformed data and compared. While the transformations tended to increase the precision of the estimators, none of the findings were affected. This was probably due to the relatively large sample sizes used in the analyses.

Student *t*-tests were used for comparisons of catch rates and ratios (Ostle, 1963), supplemented with nonorthogonal analyses of variance techniques to evaluate effects of confounding (Applebaum and Cramer, 1974; Kleinbaum and Kupper, 1978). Kendall's rank correlation coefficients (tau) were used to test for associations between bycatch species compositions (Daniel, 1978). Unless otherwise stated, tests for significance were performed at the 95 percent level of confidence ($P = 0.05$).

Results and Discussion

Catch Rates and Ratios

Contemporary (1980 and 1981) sampling effort is summarized by hours fished in Figure 1 and by spatial distribution in Figure 2. In 1980, from May through September, observers sampled 377 tows representing 1,298.3 fishing hours and collected 120 bycatch samples. Approximately the same level of effort occurred in 1981 from May through August with 341 tows sampled representing 1,003.8 fishing hours. Eighty-seven bycatch samples were collected. The distribution of sampling effort, however, did differ between years. Eleven percent of the sampling effort was outside of 10 fathoms (fm) in 1980, and 66 percent was outside of

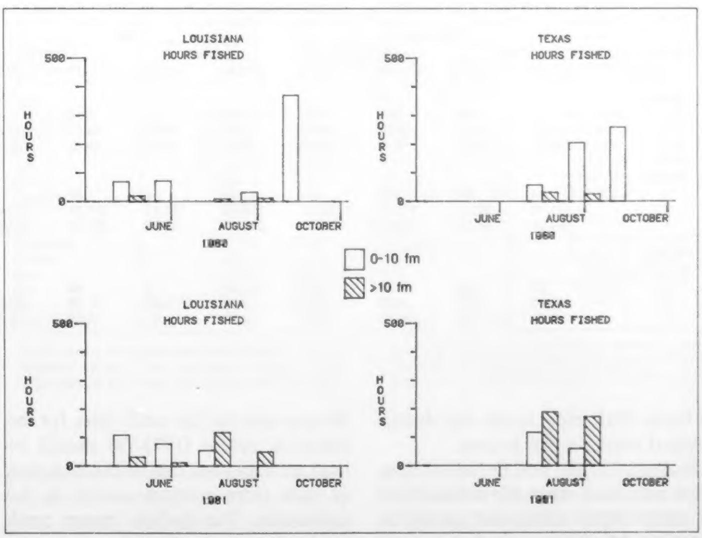

Figure 1.—Sampling effort by state, depth, and year.

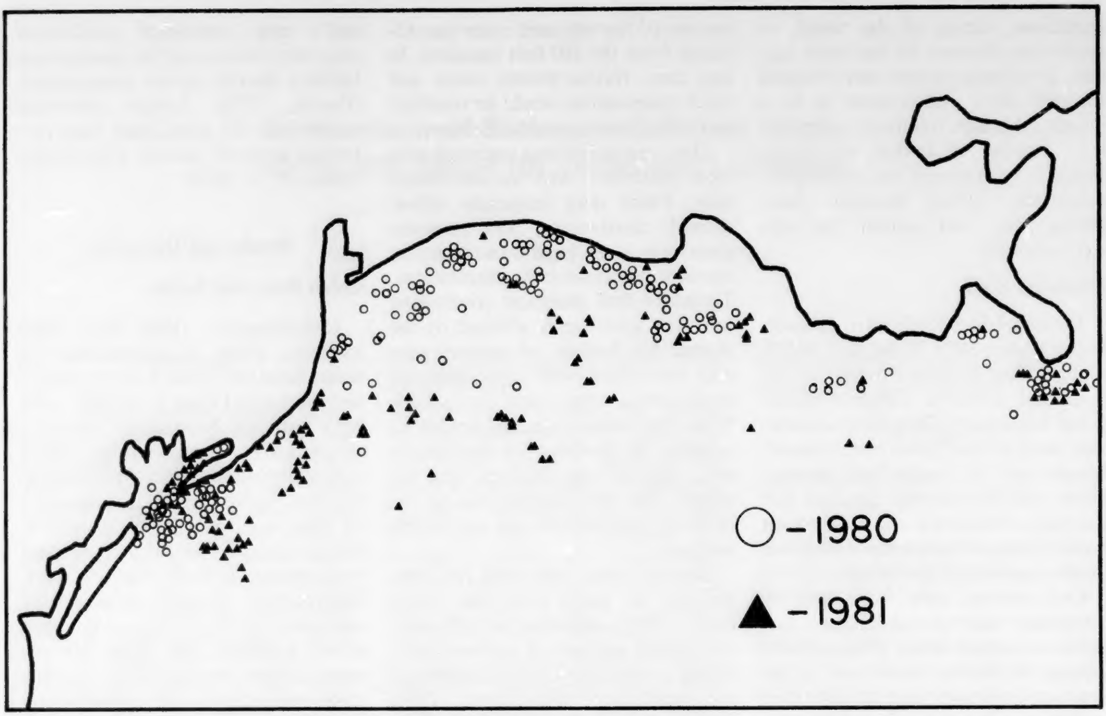

Figure 2.—Distribution of effort by year.

Table 1.—Historical (1973-78) and contemporary (1980-81) tabulation of shrimp and finfish catch rates and finfish/shrimp ratios for Texas and Louisiana.

Parameter/ statistic	Historical				1980				1981			
	Texas		Louisiana		Texas		Louisiana		Texas		Louisiana	
	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm
Shrimp												
n	54	193	206	223	135	17	210	15	58	112	94	77
$\bar{x}$	33.58	43.71	58.91	32.87	43.29	36.69	44.09	21.49	90.00	88.53	57.21	68.28
s	28.37	34.40	73.20	29.38	42.45	12.69	49.92	31.34	63.52	58.67	68.04	76.20
Finfish												
n	54	193	206	223	47	5	62	6	14	33	23	17
$\bar{x}$	301.48	92.07	441.02	222.02	356.59	120.61	214.81	532.48	257.88	113.04	474.58	320.00
s	454.87	94.53	766.27	353.80	264.15	58.98	257.02	400.22	203.72	87.78	689.91	493.07
Finfish/ shrimp												
n	54	193	206	223	47	5	62	6	14	33	23	17
$\bar{x}$	17.20	3.32	14.96	9.42	13.92	3.80	11.08	136.51	4.64	1.67	49.79	20.24
s	40.51	3.53	32.74	14.62	12.27	1.91	16.03	176.66	5.20	1.48	119.23	64.16

10 fm in 1981. How much this change affected results is not known.

Shrimp, finfish, and finfish/shrimp catch rates and ratios are summarized by state, depth zone, and period in Table 1. All shrimp weights and related computations are with heads-on. Shrimp and finfish catch rates for the historical period (1973-78) should be used with caution due to the inclusion of data from research vessels in the summaries. The finfish/shrimp catch ratios, however, should not be affected. Mean shrimp catch rates during the contemporary period ranged from a low of 21.49 pounds/hour off Louisiana (>10 fm) in 1980 to a high of 90.00 pounds/hour off Texas (0-10 fm) in 1981. Mean finfish catch rates also varied greatly, ranging from a low of 113.04 pounds/hour off Texas

(>10 fm) in 1981 to a high of 532.48 pounds/hour off Louisiana (>10 fm) in 1980. Mean finfish/shrimp catch ratios, however, exhibited the greatest variation, ranging from a low of 1.67 off Texas (>10 fm) in 1981 to a high of 136.51 off Louisiana (>10 fm) in 1980.

Significant differences in shrimp catch occurred between 1980 and 1981 off both Texas and Louisiana (Table 2), with 1981 being the best year for both states. The Texas shrimp catch rate also was significantly higher in 1981 than off Louisiana, even though there was no detectable difference between the two states in 1980.

Finfish catch rates were significantly lower off Texas than off Louisiana in 1981, while again there was no difference between the two states in 1980 (Table 2). The finfish catch rate off Texas was significantly lower in 1981 than in 1980, with the rate remaining relatively consistent off Louisiana for the two years.

Finfish/shrimp catch ratios for 1980 and 1981 essentially reflected the same general conclusions drawn from the summarized shrimp and finfish catch rate analyses (Table 2). The ratio was significantly lower off Texas in 1981 than in 1980 without a significant difference being detected for Louisiana between the two years. Texas and Louisiana were relatively similar with respect to this parameter in 1980. In 1981, the ratio was significantly lower off Texas than off Louisiana.

Historically, the finfish/shrimp catch ratio for Texas was significantly lower than for Louisiana (Table 2). The year 1980 was unusual for both states, with the ratios being significantly higher compared with the historical 5-year average (1973-78). The Texas 1981 ratio, however, was not significantly different from the historial mean. The ratio off Louisiana for 1981 was significantly higher than the ratio computed from the historical data.

Concern was expressed previously about changes in sampling coverage which occurred during the 2-year contemporary period as related to the depth zone. To satisfy this concern, a multivariant regression analysis was performed on the data. This analysis permitted examination of the effects of year, depth, and the interaction between these terms adjusted for depth (0-10 fm and >10 fm) and year (1980 and 1981).

The effect of depth on shrimp catch rates was not significant for either state (Tables 3, 4). Year (1980 and 1981) had the greatest effect which is entirely

Table 2.—Results of *t*-tests applied to comparisons of contemporary (1980-81) and historical (1973-78) shrimp and finfish catch rates and finfish/shrimp ratios for Texas and Louisiana. Catch rates are in pounds/hour/100 feet of headrope.

Difference	Sample sizes	Difference between means	Standard deviation	*t*-value
Shrimp, contemporary				
TX 1981 — TX 1980	170-152	46.47	51.74	8.05***
LA 1981 — LA 1980	171-225	19.62	60.00	3.22***
TX 1981 — LA 1981	170-171	26.83	66.27	3.74***
TX 1980 — LA 1980	152-225	− 0.02	45.79	−0.01
Finfish, contemporary				
TX 1981 — TX 1980	47-52	−177.71	214.61	−4.11***
LA 1981 — LA 1980	40-68	166.04	438.18	1.90
TX 1981 — LA 1981	47-40	−252.69	428.23	−2.74**
TX 1980 — LA 1980	52-68	91.06	273.98	1.80
Ratios, contemporary				
TX 1981 — TX 1980	47-52	− 10.39	9.03	−5.72***
LA 1981 — LA 1980	40-68	15.08	78.00	0.97
TX 1981 — LA 1981	47-40	− 34.68	67.53	−2.39**
TX 1980 — LA 1980	52-68	− 9.21	47.40	−1.05
Ratios, historical				
TX 1981 — TX Historical	47-247	− 3.80	18.32	−1.30
TX 1980 — TX Historical	52-247	6.59	18.80	2.30**
LA 1981 — LA Historical	40-429	25.15	37.53	4.05***
LA 1980 — LA Historical	68-429	10.07	32.67	2.36**
TX Historical — LA Historical	247-429	− 5.73	34.93	−2.05**

*Significant at 90 percent confidence level (P = 0.10).
**Significant at 95 percent confidence level (P = 0.05).
***Significant at 99 percent confidence level (P = 0.01).

Table 3.—Summarized regression ANOV's for Texas contemporary (1980-81) data. The full model has the form $\hat{Y} = \mu + D + P + DP + \varepsilon$, where D = depth (0-10 fm or >10 fm), P = year (1980 or 1981), and DP = interaction between depth and year.

Effect	Degrees of freedom	Mean square error	*F*
Shrimp			
Full model	3	58,032.23	21.56***
DP/D,P	1	285.89	0.11
D,P	2	86,905.40	32.37***
D/P	1	454.56	0.17
P/D	1	127,881.58	47.64***
Residual	318	2,691.98	
Finfish			
Full model	3	412,507.88	9.77***
DP/D,P	1	25,717.67	0.61
D,P	2	605,902.98	14.41***
D/P	1	432,153.27	10.28***
P/D	1	79,630.72	1.89
Residual	95	42,206.16	
Ratio			
Full model	3	1,071.46	13.82***
DP/D,P	1	158.41	2.04
D,P	2	1,527.98	19.50***
D/P	1	390.96	4.99**
P/D	1	790.17	10.08***
Residual	95	77.51	

*Significant at 90 percent confidence level (P = 0.10).
**Significant at 95 percent confidence level (P = 0.05).
***Significant at 99 percent confidence level (P = 0.01).

Table 4.—Summarized regression ANOV's for Louisiana contemporary (1980-81) data. The full model has the form $\hat{Y} = \mu + D + P + DP + \varepsilon$, where D = depth (0-10 fm or >10 fm), P = year (1980 or 1981), and DP = interaction between depth and year.

Effect	Degrees of freedom	Mean square error	*F*
Shrimp			
Full model	3	16,573.62	4.62***
DP/D,P	1	11,927.47	3.32*
D,P	2	18,896.69	5.23**
D/P	1	410.95	0.11
P/D	1	26,747.33	7.41***
Residual	392	3,587.40	
Finfish			
Full model	3	493,326.59	2.67*
DP/D,P	1	782,248.12	4.24**
D,P	2	348,865.83	1.83
D/P	1	3,376.06	0.02
P/D	1	550,026.98	2.89*
Residual	104	184,539.58	
Ratio			
Full model	3	33,440.25	6.32***
DP/D,P	1	84,241.10	15.92***
D,P	2	8,039.82	1.33
D/P	1	10,363.24	1.71
P/D	1	842.19	0.14
Residual	104		

*Significant at 90 percent confidence level (P = 0.10).
**Significant at 95 percent confidence level (P = 0.05).
***Significant at 99 percent confidence level (P = 0.01).

consistent with results given in Table 2. Depth, however, significantly affected both finfish catch rates and finfish/shrimp ratios. Notable was the effect of depth on finfish catch rates off Texas where, when year was adjusted for depth, the effect of year was no longer significant (Table 3). In other words, finfish catch rates off both Texas and Louisiana did not change significantly from 1980 to 1981 when adjusted for depth. The effect of depth on finfish/shrimp catch ratios was mixed between the two states, presumably because the ratios manifest changes in both shrimp and finfish catches. Its effect off Texas was significant, but not to the extent which would require adjustments to conclusions reached in Table 2. Confounding of the effect of depth by year (i.e., significant interaction) occurred off Louisiana, thereby obscuring main effects of the two parameters (Table 4).

Table 5.—Summarized regression ANOV for historical (1973-78) finfish/shrimp catch ratios. The full model has the form $\hat{Y} = \mu + D + S + DS + \epsilon$, where D = depth (0-10 fm or >10 fm), S = state (Texas or Louisiana), and DS = interaction between depth and state.

Effect	Degrees of freedom	Mean square error	F
Full model	3	5,520.57	10.40***
DS/D,S	1	2,109.32	3.97**
D,S	2	7,226.20	13.56***
D/S	1	9,312.25	17.47***
S/D	1	1,959.59	3.68*
Residual	672	530.61	

*Significant at 90 percent confidence level (P = 0.10).
**Significant at 95 percent confidence level (P = 0.05).
***Significant at 99 percent confidence level (P = 0.01).

The effect of depth on historical finfish/shrimp catch ratios also was examined through a regression analysis of variance (Table 5). Its effect, adjusted for state, was highly significant even though confounded by the effect of state (i.e., significant interaction). The effect of state, adjusted for depth, was not significant at the 95 percent confidence level.

Species Composition

The 13 most commonly occurring shrimp bycatch species (occurred in more than 50 percent of the catches) are listed by percent of total catch in Table 6. Sciaenids dominate the listings with Atlantic croaker, *Micropogonias undulatus,* comprising the greatest percentage of bycatch for an individual species in all but two of the lists.

Percentages for the different states, time periods, and depth zones were ranked and used to evaluate differences in species composition (Fig. 3). Correlations were assumed significant at the 90 percent level of confidence.

Species composition rankings, when averaged across depth zone, were generally dissimilar between states and time periods. When the rankings were stratified by depth zones, however, significant similarities were found (Fig. 3). Specifically, all shallow-water areas (0-10 fm) were similar in species composition regardless of state or time period. Findings for the deeper water areas (>10 fm) were mixed, with Texas and Louisiana generally being dissimilar between years. Within states, however, the rankings were generally similar between years with the exception of 1980 for both states. Comparisons between shallow- and deep-water species composition rankings were consistently dissimilar by state between years.

The rankings suggest that within the shallow-water areas, species compositions have not changed significantly from the historical period to 1981. Bycatch composition in the offshore areas, however, seems to be much more variable spatially and temporally.

Summary and Conclusions

Shrimp catch rates increased significantly off Texas and Louisiana between 1980 and 1981, with Texas experiencing the greatest increase. This finding was consistent with the hypothesis that the Texas closure had a positive effect on the Texas shrimp fishery. The effect of the closure on finfish catch rates (i.e., the shrimp fleet bycatch) was not clear even though catch rates were significantly lower for Texas in 1981 than for Louisiana. One year earlier there was no significant difference in the rate for the two states. The primary reasons for the difference can be presumed to result from either a sampling bias toward the offshore Texas waters (i.e., >10 fm) or a shift by the 1981 Texas shrimp fleet toward these offshore waters. Water depth was shown to have a significant effect on finfish catch rates, but not on

Table 6.—Percent of total bycatch biomass for selected species for historical (1973-78) and contemporary (1980-81) catches.

	Louisiana						Texas					
	Historical		1980		1981		Historical		1980		1981	
Species	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm	0-10 fm	>10 fm
Micropogonias undulatus	43.70	25.28	36.68	62.18	43.37	22.94	16.45	6.48	44.08	6.63	13.61	13.00
Arius felis	3.23	1.77	11.32	1.30	3.18	0.04	3.13	0.26	2.64	2.16	0.85	0.57
Chloroscombrus chrysurus	3.57	0.27	7.22	0.90	1.92	0.81	1.25	0.78	6.69	0.21	10.63	11.41
Menticirrhus americanus	0.59	0.03	6.10	0.63	0.73	0.03	2.83	0.59	1.71	0.55	6.59	1.59
Callinectes sapidus	2.48	0.30	5.07	0.47	3.50	2.23	0.53	1.78	0.67	6.80	3.22	18.05
Leiostomus xanthurus	4.39	3.33	4.84	4.08	7.57	0.12	1.73	0.82	0.67	1.08	3.37	0.18
Cynoscion arenarius	6.15	2.89	3.72	4.98	2.47	0.03	2.14	0.51	4.29	2.82	2.40	1.24
Cynoscion nothus	1.00	3.08	3.58	2.87	0.13	0.19	5.31	2.75	5.36	0.99	10.35	7.34
Trichirus lepturus	2.59	2.38	3.44	1.60	8.79	21.59	1.63	0.16	2.10	0.29	6.94	0.60
Peprilus burti	0.62	1.56	1.54	1.58	2.53	1.16	2.08	3.03	0.76	1.66	8.10	8.05
Stenotomus caprinus	0.27	10.63	0.47	2.27	0.05	5.31	1.03	2.21	1.23	34.74	0.43	7.08
Loligo pealei	0.15	0.03	0.46	0.73	0.10	0.21	0.85	1.80	0.53	2.40	1.28	3.98
Synodus foetens	0.14	5.64	0.33	0.05	0.15	3.22	1.23	4.69	0.31	3.15	0.74	3.98

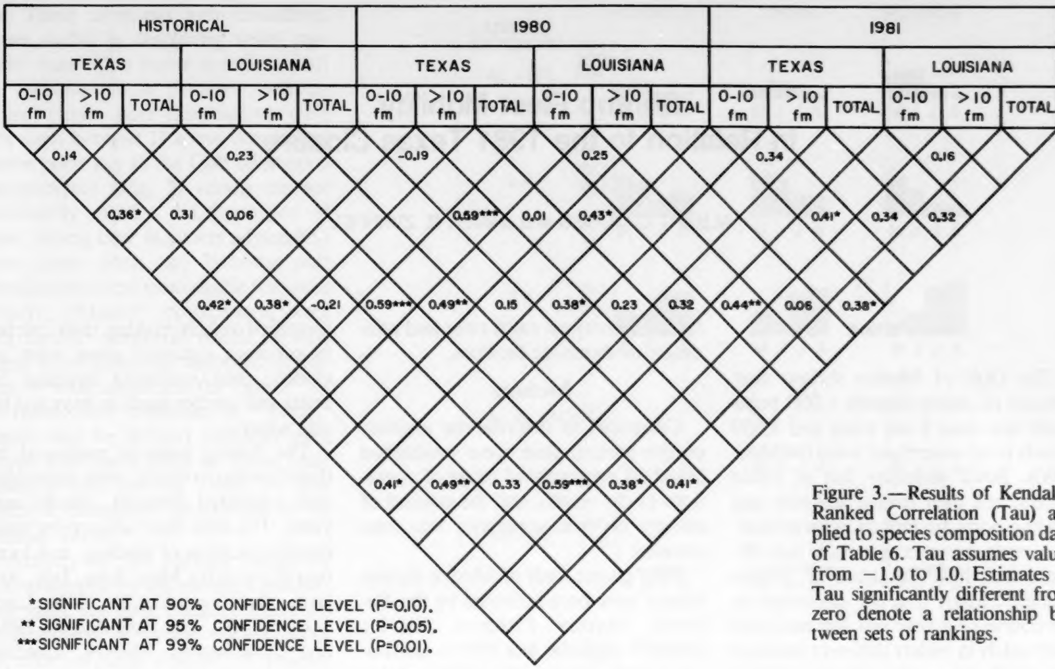

Figure 3.—Results of Kendall's Ranked Correlation (Tau) applied to species composition data of Table 6. Tau assumes values from −1.0 to 1.0. Estimates of Tau significantly different from zero denote a relationship between sets of rankings.

catch rates for shrimp during the 2-year sampling period.

Species composition of the bycatch was relatively consistent in the shallower waters for both states and all time periods, regardless of the Texas closure. This suggests these stocks are relatively stable. On the other hand, the composition of the deeper water bycatch varied significantly between years and by state, and the composition of deeper-water catches was different from catches in the shallower waters. Composition of the offshore Texas bycatch in 1981 was different from the bycatch in 1980, but not different from the historical average.

Use of finfish/shrimp catch ratios to judge effects of the closure appears to be questionable. Changes in either or both the shrimp and finfish catch rates affect the ratio. For example, the 1981 Texas ratio was different from the historical average, but since 1981 was an unusually good year for shrimp, a change in the ratio should be expected. Unfortunately, there was no way to determine if the difference was solely due to differences in catch rates for shrimp, for finfish, or for both species groupings.

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Shrimp Fleet Mobility in Relation to the 1981 Texas Closure

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Introduction

The Gulf of Mexico shrimp fleet consists of approximately 5,000 boats (craft less than 5 net tons) and 3,500 vessels (craft over 5 net tons) (NOAA, 1980). Boats generally fish in inside waters, and their fishing activities and landing ports are limited geographically. Vessels, however, generally fish offshore and have considerably greater mobility. Many (but not all) vessels in the course of a year will fish and land their catch in widely different parts of the Gulf. Operators change fishing grounds in response to the unique seasonal abundance patterns of shrimp in different areas and change landing ports to maintain an acceptable ratio between fishing time and transit time to and from the fishing grounds.

In 1981, state and federally managed waters off Texas were closed to brown shrimp fishing from 22 May through 15 July. Because coastal waters offshore of other states along the Gulf of Mexico were not closed to fishing at this time, concern was expressed that vessels normally fishing off Texas during this period would fish in these other areas. It was feared that this fishing might adversely affect catch rates or overload shoreside processing facilities in these areas.

This study was undertaken to provide information on the seasonal fishing activities of the Gulf shrimp fleet. The study describes the mobility of western Gulf shrimp vessels, compares fleet mobility in 1981 with that in earlier years, and relates the results to the 1981 closure of the Texas brown shrimp fishery. Companion studies in this series address the effect of this fishing activity on catch rates and utilization of shoreside facilities.

Methods

Categories to describe the mobility of the shrimp fleet were established based on geographical range of operations of the vessels, and the amount of activity in these categories was enumerated.

Data on the Gulf of Mexico shrimp fishery have been collected by the National Marine Fisheries Service (NMFS) since the late 1950's. Statistical agents obtain information from dealer records or by interview with vessel captains. Vessel identification, date of landing, port of landing, pounds landed, and statistical area fished are recorded for most vessel trips. Records for some smaller ports visited less frequently by agents and records obtained from secondary dealers and processors are generally consolidated and may not contain information on individual vessels or individual trips. Consequently, NMFS data, although not a total census of all the landed catch, provide an excellent description of the general shrimp fishing patterns in the Gulf.

Records utilized in this study were those containing a vessel identification number and recorded as landed at ports in Alabama, Mississippi, Louisiana, and Texas in May through August 1981 and June through August 1980 and 1970-74. Only landings by identified vessels making their catches in offshore statistical areas were included, thus excluding landings by boats and catches made in bays and inside waters.

The fishing patterns portrayed by these landings records were assembled and compared between months and years. The data were arrayed by year, month, location of landing, and location of catch for May, June, July, August, and June-August 1981; June, July, August, and June-August 1980; and June-August 1970-74. Landing location was summarized geographically by category: Alabama/Mississippi (AL/MS), Louisiana (LA), Texas (TX), and combinations (indicated by hyphenated categories) of these states. Alabama and Mississippi were combined in one category because of their relatively short coastlines. Landings of vessels at Florida ports were not included in the analysis because data for 1980 were not available. Catch location was summarized by the following statistical areas: Areas 1-9 (off Florida), areas 10-12 (off Alabama, Mississippi, and Louisiana east of the Mississippi River), areas 13-16 (off Louisiana west of the Mississippi River), area 17 (an area divided by the seaward extension of the Louisiana-Texas border), and areas 18-21 (off Texas). Areas 18-21 and the Texas portion of area 17 were included in the 22 May-15 July closure. Each vessel was categorized according to its landing locations (in one state or in a combination of states) during a given time period. For example, vessels were grouped together that landed only in Texas, only in Louisiana, in both Louisiana and Texas (designated Louisiana-Texas),

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etc. These categories were considered more useful in describing vessel mobility than either home port (i.e., port of registration) or "home" designations. Home port designations were not used because 1) some vessels had home ports not in the Gulf of Mexico geographical area, 2) vessels do not necessarily spend a major portion of their fishing time in waters adjacent to their home port, and 3) home port designations were unavailable for some vessels. "Home" designations were not used to categorize vessels because there is no generally accepted definition of what constitutes the "home" of a vessel. For example, a "Texas" vessel may be defined variously as a vessel that lands only in Texas, that lands at any time in Texas, or that lands a designated proportion of its trips in Texas.

Activity in the various categories was evaluated by calculating a percentage value for each category based on total number of vessels, total number of trips, or total number of pounds landed. These percentage values were then compared, either subjectively or statistically, as described in the next section, to interpret the impact of the closure regulation on vessel activity and fleet mobility.

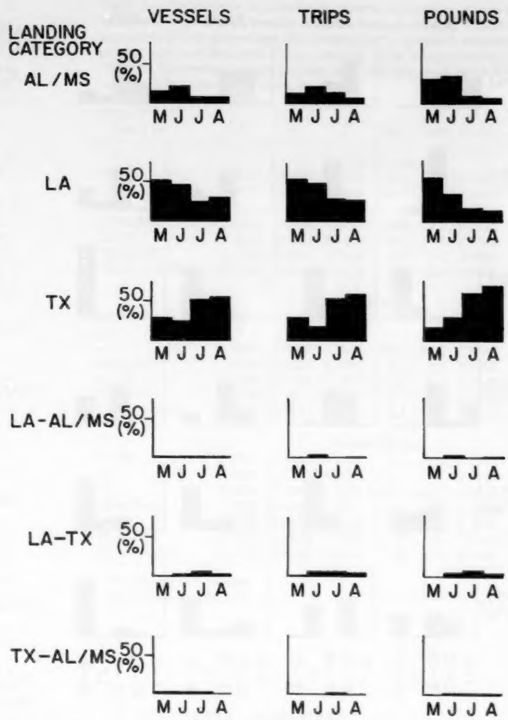

Figure 1.—Distribution of activity of shrimp vessels in the western Gulf of Mexico, May through August 1981, measured as number of vessels operating, number of trips made, and number of pounds landed. Monthly activity is shown for each area landing category (by state or states) as a percentage of total activity for that month.

Results

Fishing activities of the western Gulf shrimp fleet during each month from May through August 1981 are shown in Figure 1. First, activity for each state category was expressed as a percentage of the total number of vessels participating in the fishery in each month. Thus, in May 1981, 17 percent of the vessels landed in Alabama/Mississippi, 51 percent landed in Louisiana, 30 percent landed in Texas, 0.5 percent landed in Louisiana and Alabama/Mississippi, 1.0 percent landed in Louisiana and Texas, and 0.2 percent landed in Texas and Alabama/Mississippi. Corresponding values for June, July, and August are also shown in Figure 1. These results indicate that in 1981 over 90 percent of the vessels landed in only one state during a month, fewer than 10 percent landed in two states in any month, and no vessels were recorded as landing in three states. The percentages of vessels landing in Alabama/Mississippi and in Louisiana were higher in May and June than in July and August. Conversely, the percentages of vessels landing in Texas were lower in May and June than in July and August. Of the vessels landing in two states in a single month, landings in Louisiana-Texas were most frequent (as high as 7 percent), landings in Louisiana-Alabama/Mississippi were next most frequent (as high as 2 percent), and landings in Texas-Alabama/Mississippi were least frequent (as high as 1.3 percent).

Second, activity was expressed as a percentage of the number of trips completed and the number of pounds landed. These results for each state are also shown in Figure 1. Over 90 percent of the completed trips and over 90 percent of the pounds landed each month were by vessels landing in single states, and less than 10 percent were from vessels operating in two states. Activity at Alabama/Mississippi and Louisiana ports was generally higher in May and June than in July and August, whereas activity at Texas ports was lower in May and June than in July and August. Of the trips and pounds landed in two states in any single month, Louisiana-Texas was the most frequent category. Thus the three measures of activity patterns—vessel, trips, and pounds landed—are comparable.

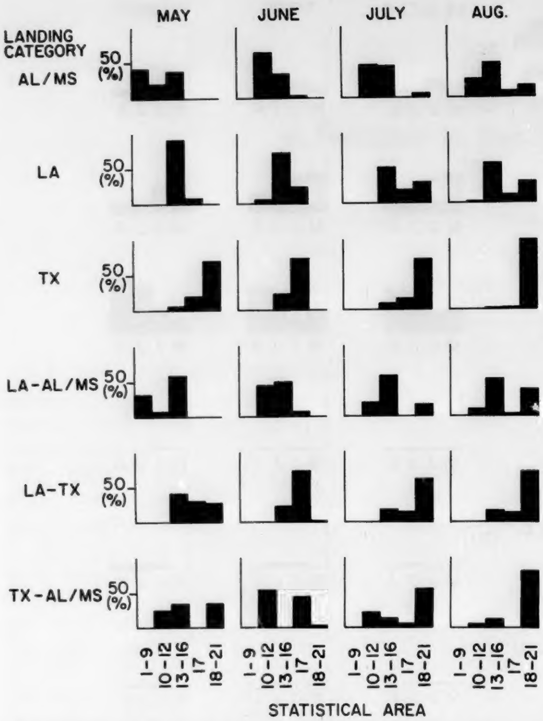

Figure 2.—Distribution of activity of shrimp vessels in the western Gulf of Mexico, May through August 1981, as measured by location of the catch within each area landing category. Activity is shown as catch taken in statistical areas 1-9 (off Florida), 10-12 (off Alabama, Mississippi, and Louisiana east of the Mississippi River), 13-16 (off Louisiana west of the Mississippi River), 17 (off Louisiana-Texas), and 18-21 (off Texas) as a percentage of total catch for that month and area landing category.

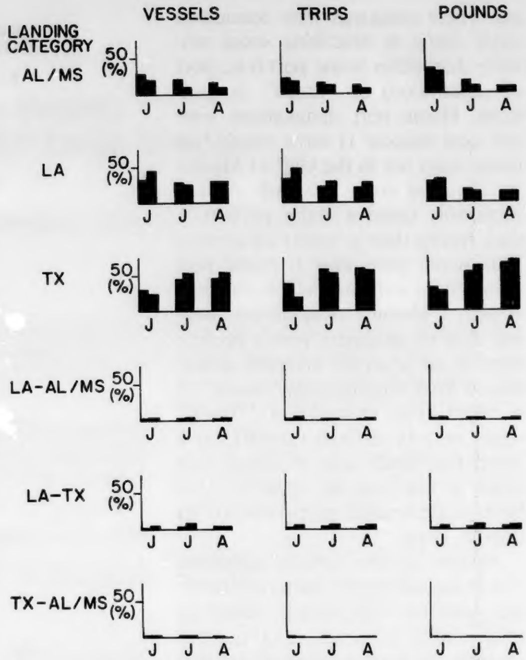

Figure 3.—Distribution of activity of shrimp vessels in the western Gulf of Mexico, June through August 1980 (left bar) and 1981 (right bar), measured as number of vessels operating, number of trips made, and number of pounds landed. Monthly activity is shown for each area landing category (by state or states) as a percentage of total activity for that month.

Fishing activity patterns in 1981 were further described by comparing the locations of capture with the location of landing (Fig. 2). Vessels landing in Alabama/Mississippi, Louisiana, or Texas fished primarily in the offshore areas of the respective state where they landed and secondarily off an adjacent state. Vessels landing in Alabama/Mississippi fished off Florida (areas 1-9) and Louisiana (areas 13-16) in May, as well as off their own state areas. In later months the fishing activity of vessels landing in Alabama/Mississippi shifted to the west. Vessels landing in Louisiana fished mainly off that state. They seldom fished off Alabama/Mississippi (areas 10-12), but fished to a greater extent off Texas (areas 18-21) in July and August. Vessels landing in Texas fished mainly off that state in May, to a major extent off Louisiana (areas 13-16) in June and July, but again almost entirely off Texas in August.

Another aspect of fishing activity patterns, month-to-month variation, was examined by comparing 1981 patterns with those in 1980 (Fig. 3). Similarities as well as differences in the two years were apparent. The majority (96-98 percent) of vessels landing in June, July, or August in both 1980 and 1981 landed in only a single state. Fewer than 5 percent of the vessels landed in more than one state in any month. The percentage of vessels landing in Alabama/Mississippi in 1980 decreased from June to August, although less so than in 1981, and the percentage of vessels landing in Texas increased, but not as much as in 1981. The percentages of vessels landing in more than one state in 1980 (2.2 percent in June, 4.2 percent in July, and 3.5 percent in August) were less than in 1981 (5.5 percent, 9.4 percent, and 4.2 percent, respectively). In both July and

Table 1.—Activity by state(s) of landing of selected shrimp vessels in the western Gulf of Mexico in June through August 1981, 1980, and 1970-74. State categories included were Alabama/Mississippi, Louisiana, and Texas and their combinations. Percentage of vessels landing in the state, percentage of trips, and percentage of pounds landed are shown. Selected vessels are those identified by vessel documentation number; thus, percentages in the table are based on only the identified vessel portion of total fleet operations.

State of operation	1981	1980	1974	1973	1972	1971	1970
			Percentage of vessels				
AL/MS	12.4	19.3	12.9	13.5	14.2	15.8	16.8
LA	30.7	30.5	21.8	19.6	24.1	23.4	23.4
TX	41.4	41.0	47.6	51.6	47.1	40.5	39.5
LA-AL/MS	3.6	3.7	4.8	2.3	3.3	4.3	4.7
LA-TX	9.7	4.4	12.1	10.4	9.2	1.1	12.9
TX-AL/MS	1.8	0.9	1.0	1.9	1.5	1.9	1.5
TX-LA-AL/MS	0.6	0.2	0.5	0.8	0.6	0.8	1.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
			Percentage of trips				
AL/MS	10.0	14.5	10.2	13.6	14.2	16.0	15.8
LA	25.9	23.5	14.8	11.8	18.0	17.8	15.6
TX	43.0	50.5	55.7	59.0	52.1	43.3	33.0
LA-AL/MS	4.1	4.0	2.1	2.3	3.4	5.0	11.6
LA-TX	14.0	6.3	12.9	10.2	9.7	14.2	11.6
TX-AL/MS	2.1	0.9	1.8	2.1	1.9	2.7	1.8
TX-LA-AL/MS	0.9	0.3	0.7	1.0	0.6	1.0	1.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
			Percentage of pounds landed				
AL/MS	10.5	16.0	12.5	10.5	12.6	15.5	13.9
LA	15.7	17.7	12.2	9.8	15.0	17.4	16.7
TX	53.1	54.0	54.9	62.8	55.9	40.4	42.7
LA-AL/MS	4.4	4.9	4.7	2.3	3.9	6.2	5.9
LA-TX	13.5	5.4	13.4	11.2	10.0	16.2	16.7
TX-AL/MS	2.0	1.5	1.4	2.4	1.9	3.1	2.2
TX-LA-AL/MS	0.8	0.4	0.9	0.9	0.8	1.1	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 2.—Comparison of activity by state(s) of landing of selected shrimp vessels in the Gulf of Mexico in June through August 1980-81. Average logarithm of the percentage distribution ($\ln P$), standard deviation ($\hat{\sigma}$), and pooled standard deviation ($\tilde{\sigma}$) for vessels, trips, and pounds are shown for 1970-74. Percentage values for 1981 and 1980 (P_{81}/P_{80}), and the normalized variable z are discussed in the text.

State of operation	$\ln P$	$\hat{\sigma}$	$\tilde{\sigma}$	1981	1980	P_{81}/P_{80}	z
			Number of vessels				
AL/MS	2.6789	0.1097	0.1680	12.4	19.3	0.6425	−1.86*
LA	3.1090	0.0833	0.1833	30.7	30.5	1.0066	0.025
TX	3.8072	0.1144	0.1611	41.4	41.0	1.0098	0.043
LA-AL/MS	1.3203	0.3106	0.3847	3.6	3.7	0.9730	−0.050
LA-TX	2.4368	0.1521	0.1868	9.7	4.4	2.2045	2.99**
TX-AL/MS	0.4189	0.2633	0.2448	1.8	0.9	2.0000	2.00**
TX-LA-AL/MS	−0.2776	0.3621	0.3772	0.6	0.2	3.0000	2.06**
			Total trips				
AL/MS	2.6595	0.2276	0.1680	10.0	14.5	0.6896	−1.56
LA	2.7711	0.1915	0.1833	25.9	23.5	1.1021	0.375
TX	3.8982	0.1708	0.1611	43.0	50.5	0.8515	−0.706
LA-AL/MS	1.2189	0.4323	0.3847	4.1	4.0	1.0250	0.045
LA-TX	2.4859	0.1766	0.1868	14.0	6.3	2.2222	3.02**
TX-AL/MS	0.7506	0.1571	0.2448	2.1	0.9	2.3333	2.45**
TX-LA-AL/MS	0.0673	0.4022	0.3772	0.9	0.3	3.0000	2.06**
			Pounds landed				
AL/MS	2.5567	0.1442	0.1680	10.5	16.0	0.6562	−1.7732*
LA	2.6327	0.2393	0.1833	15.7	17.7	0.8870	−0.462
TX	3.9244	0.1889	0.1611	53.1	54.0	0.9833	−0.074
LA-AL/MS	1.4682	0.4008	0.3847	4.4	4.9	0.8980	−0.198
LA-TX	2.5828	0.2244	0.1868	13.5	5.4	2.5000	3.47**
TX-AL/MS	0.7547	0.2938	0.2448	2.0	1.5	1.3333	0.831
TX-LA-AL/MS	0.0709	0.3662	0.3772	0.8	0.4	2.0000	1.30

*Significant at 0.10 level.
**Significant at 0.05 level.

August 1980 a few vessels reported landings in three states (not shown in Figure 3), whereas in 1981 no vessel was reported to have landed in three states in any single month from June through August. Similarities and differences in fishing activity between 1980 and 1981 that were indicated by number of vessels reported were also indicated by trips completed and pounds landed.

A further comparison between 1981 and 1980 was made by combining records for June, July, and August for each of these years and for 1970-74 (Table 1). Records for 1975-79 were not collected in a manner suitable for this comparison and thus were not used. June, July, and August were chosen because they included two approximately equal time periods—a period of regulation (1 June through 15 July) and an unregulated period (16 July through 31 August). Thus, comparisons using a 3-month period of observation allowed conclusions about shifts in fishing activity that encompassed a longer time than one month and that incorporated the effects of the closure regulation both during and immediately following the closure period.

The base year of 1980 was used for assessing changes resulting from the increased regulations in 1981. The percentages of vessels, trips, and landings for each of the four major categories or groupings (TX, LA, AL/MS, LA-TX) for 1981 were: TX (41, 43, 53, for vessels, trips, and landings, respectively), LA (31, 26, 16), AL/MS (12, 10, 10), and LA-TX (10, 14, 14). For 1980, the corresponding results were: TX (41, 50, 54), LA (30, 24, 18), AL/MS (19, 14, 16), and LA-TX (4, 6, 5). For 1970-74, the minimum and maximum values for each category were: TX (40-50, 33-59, 40-63), LA (20-24, 12-18, 10-17), AL/MS (13-17, 10-16, 10-16), and LA-TX (1-13, 10-14, 10-17). In general, 1980 results fell midway between the minimum and maximum values for 1970-74. However, a consistent shift from the LA-TX category to the LA alone category occurred over this period. Results for all categories are shown in Table 1.

Additional comparisons between years (Table 2) were made for distributions of vessels, trips, and landings in the June-August period. The total number of identified vessels was generally stable within the two periods 1980-81 and 1970-74. The year-to-year variability (in percent) for vessels, trips, and landings for the period 1970-74 was used to assess the "significance" of the changes from 1980 to 1981. Means and variances ($\ln P$ and $\hat{\sigma}^2$, respectively) of logarithms of percentage values for 1970-74 were calculated and used to make this assessment. As shown in Table 2, variance estimates calculated for the logarithms of the percentages were similar for vessels, trips, and pounds landed with-

same landing category. As expected, variability was less for vessels, trips, and landings for a single state and was greater for activities encompassing three states. A pooled estimate of variance $\bar{\sigma}^2$ (calculated from vessels, trips, and pounds) for each landing area was used to determine whether changes from 1980 to 1981 should be considered usual or unusual. The statistic:

$$z = ln(P_{81}/P_{80}) / \sqrt{2\bar{\sigma}^2}$$

where z = normalized variable,
P_y = percentage of activity (vessels, trips, or pounds) in a given landing area in year y, and
$\bar{\sigma}^2$ = pooled estimate of variance calculated for each landing area for vessels, trips, and pounds.

Significantly higher percentage frequencies in 1981 compared with 1980 occurred in the following categories: Louisiana-Texas, Texas-Alabama/Mississippi, and Texas-Louisiana-Alabama/Mississippi (Table 2). Percentage ratios between these two years were outside the range expected from historical values. These categories included 3 percent of the identified vessels, 4 percent of their trips, and 3 percent of their landings in 1981, and thus represented only a minor portion of the total fleet activity in that year. The higher frequencies that occurred in the two- and three-state categories indicate an increase in vessel mobility in 1981 compared with 1980. This increase in vessel mobility is possibly due to the Texas closure. Furthermore, observations on fishing practices in 1981 are consistent with this conclusion. Many vessels fished off Louisiana in June and July and off Texas in July and August because of the closure, and these vessels probably contributed to the numbers in the two- or three-state landing categories.

Summary

The relationship between state(s) of landing and fishing activity of individually identified Gulf shrimp vessels, as measured by frequency of vessels, trips, and pounds landed for 1981, were examined in this study. The distribution of pounds landed by area of capture was also examined. Emphasis was on vessels operating in the western Gulf.

In June-August 1981, most vessels landed in only one western Gulf state, but some vessels (15 percent) landed in more than one state, especially Louisiana-Texas. The data indicate that probably the majority of catch was taken offshore of the respective states of landing.

Fishing activity patterns in June-August indicated significantly more fleet movement in 1981 compared with 1980. More activity (as measured by percentage of vessels, trips, or pounds) was observed for landing categories encompassing two or more states. Less fleet activity was observed in 1981 than in 1980 in the Alabama/Mississippi category. Since the ratio of activities between 1981 and 1980 in these areas is outside the range of historical values, we concluded that this is likely to be due to imposition of the Texas closure in 1981. The change of mobility includes the shift to grounds away from Texas during the closure period and the shift to grounds off Texas after the closure ended. Although the difference between 1980 and 1981 was statistically significant, the majority of fishing activity in each year was by vessels that landed in only a single state during the June-August period.

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Survey of Ice Plants in Louisiana, Mississippi, and Alabama, 1980-81

JOHN M. WARD and JOHN R. POFFENBERGER

Introduction

Reports of ice shortages during the shrimp fishing season prompted a National Marine Fisheries Service, Southeast Fisheries Center study to determine the impact of the Texas closure regulation on ice plant production and sales. Like Texas, Louisiana controls the opening of the nearshore and inshore shrimp seasons. In the initial days of the season when shrimp are moving out of the inshore areas and are relatively abundant, the shrimp fishing effort is high. A large part of this effort is by recreational or part-time fishermen who own relatively small boats and use butterfly nets or small trawls to catch shrimp. There are estimated to be several thousand of these fishermen, and they increase the demand for the various dockside facilities during the opening days of the shrimp fishing season. More importantly, this surge in fishing effort occurs coincidentally with the period of the regulated Texas closure.

ABSTRACT—This report presents the findings of the 1980-81 survey of ice plants in the coastal areas of Louisiana, Mississippi, and Alabama. The survey was undertaken by the National Marine Fisheries Service's Southeast Fisheries Center to determine the impact of the Texas closure regulation on the level of ice sales in this region. The 1980 survey was limited to Louisiana ice plants during the 13-week period of the spring brown shrimp season. The 1981 survey of Louisiana, Mississippi, and Alabama ice plants covered an 18-week period. The two surveys were compared using the 13-week period of the 1980 Louisiana survey. Results of the analysis indicate that weekly ice sales did not exceed productive and storage capacity in either year despite both the increased shrimp landings and the Texas closure regulation in 1981.

In this paper we present and compare the results of the 1980-81 survey of production and sales of ice by plants in coastal Louisiana, Mississippi, and Alabama. The objective of the survey was to provide a data base that could be used to measure the ice production, storage capacity, and sales during this period of high demand. These data provided additional information on the conditions in the Gulf of Mexico shrimp fisheries during the period of the shrimp fishing closure in state and federally controlled waters off the coast of Texas.

Description of Survey and Analysis of Results

The 1980 survey was limited to the 22 ice-making facilities that supply ice to fishermen along the coast of Louisiana west of the Mississippi River. During 1981, 42 ice plants were surveyed in Mississippi, Alabama, and Louisiana. In 1981, the number of ice plants operating in Louisiana increased from 22 to 24. As a result, the comparison of the 1980 and 1981 surveys was limited to the ice plants in the Louisiana area.

In order to estimate the demand for ice, the survey consisted of collecting data on the daily amount of ice sold by the plants from May to August during 1980 and 1981. Fortunately, the clientele using these ice plants consists almost entirely of shrimp fishermen. The results are reported in the "Total sales" column of Tables 1-3 (ΣS_{wi} in Equation (1)).

To estimate the supply of ice, the plant managers were asked to rate their plant operating capacity, i.e., the actual level of daily ice production. These estimates ranged from 75 to 90 percent of the manufacturer's rating of maximum daily ice production. The ice sales data collected also indicated that most plants operated fewer than 7 days a week. Therefore, the manufacturer's daily rated capacity was reduced by 15 percent, and the plants were assumed to operate only 6 days a week to pro-

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Table 1.—Ice production and sales (in blocks of ice) for Louisiana plants, 1980[1].

No.	Week	Operating capacity: Daily[2]	Operating capacity: Weekly[3]	Total sales	Total sales as a percent of weekly operating capacity
1	5/19-5/25	10,200	52,020	30,888	59
2	5/26-5/31	11,000	56,100	31,159	56
3	6/1-6/8	11,900	60,690	31,781	52
4	6/9-6/15	12,053	61,470	28,563	46
5	6/16-6/22	12,053	61,470	26,842	44
6	6/23-6/29	12,053	61,470	24,235	39
7	6/30-7/6	12,053	61,470	22,896	37
8	7/7-7/13	12,053	61,470	22,465	37
9	7/14-7/20	10,673	54,432	18,544	34
10	7/21-7/27	10,673	54,432	18,908	35
11	7/28-8/3	10,673	54,432	20,281	37
12	8/4-8/10	10,673	54,432	20,082	37
13	8/11-8/17	7,206	36,751	16,545	45
Total			730,639	313,189	43[4]

[1]These data are from "A Report on a Survey of Ice Plants in Western Louisiana" prepared by John Poffenberger in December 1980 based on 22 ice plants. To convert to pounds or tons, multiply these figures by 300 or 0.15, respectively.
[2]This column presents the sum of the rated capacities of the ice plants on a daily basis, which may vary from week to week because some plants did not report sales for every week.
[3]Weekly capacity is defined as 85 percent of daily rated plant capacity operating 6 days per week.
[4]Mean value of total sales as a percent of weekly capacity.

vide a realistic estimate of the weekly operating capacity.

The column labeled "Daily Operating Capacity" in Tables 1-3 provides the manufacturer's daily rated capacity for all plants that reported ice sales during that week (ΣC_{di} in Equation (1)). This figure varies from week to week since weekly ice sales data were not reported by all ice plants. Therefore, if a plant did not report its sales, its capacity was not included in this total. The next column provides the weekly operating capacity which is 85 percent of the daily operating capacity for 6 days as described above (5.1 ΣC_{di} in Equation (1)). The final column presents the percent of the weekly operating capacity that was sold, i.e.:

$$\frac{\sum_{i=1}^{n} S_{wi}}{5.1 \sum_{i=1}^{n} C_{di}} \times 100 \qquad (1)$$

where ΣC_{di} = daily capacity of plant i,
ΣS_{wi} = weekly sales of plant i, and
n = number of plants.

A comparison of 1980 and 1981 surveys for Louisiana is presented in Table 4. This comparison is limited to the 13-week period of the 1980 survey. Columns labeled "Percent Utilization" present sales as a percent of operating capacity for 1980 and 1981.

Finally, ice storage capacity information was collected. Such information is useful in determining the potential effects of increased demand for ice. Reported estimates by the plant managers indicate that there was an increase in storage capacity from 30,900 to 42,900 blocks of ice in Louisiana between 1980 and 1981. In addition, 1981 estimates for Mississippi and Alabama indicated a storage capacity of approximately 12,670 blocks of ice. If the demand for ice is at or exceeds the operating capacity of the ice plants and if the demand is distributed geographically the same as supply, then this storage capacity could temporarily avert shortages in supply. The time span for which shortages will be prevented is commensurate with the amount that demand exceeds capacity. For example, based on 1981 survey data, a daily ice demand of 10,000 blocks greater than operating capacity will cause shortages in about 5 days.

Conclusions

The 1980 and 1981 surveys in Louisiana, Mississippi, and Alabama indicate that there were no shortages of ice on a weekly basis. The daily data indicate that bottlenecks did occur at various ice-loading facilities in Mississippi and Alabama. These bottlenecks, resulting in the queueing of vessels for several days, were due mainly to the reported surge in the demand for ice by part-time and recreational fishermen during the beginning of the season. While some excesses of daily ice sales over operating capacity were reported, storage capacity was apparently sufficient to prevent shortages.

Louisiana's 1980 weekly ice sales ranged from 34 to 59 percent of operating capacity during the 13-week survey with a mean value of 43 percent (Table 1). In 1981, Louisiana's weekly ice sales ranged from 16 to 57 percent of operating capacity during the 19-week survey, with a mean value of 38 percent (Table 2). Also, in 1981, Mississippi and Alabama's weekly ice sales ranged from 32 to 87 percent of operating capacity during the 19-week survey with a mean value of 56 percent. If the same 13-week period of the 1980 survey (Table 1) is used in the 1981 survey of Louisiana (Table 2), the

Table 2.—Ice production and sales (in blocks of ice) for Louisiana plants, 1981[1].

No.	Week	Operating capacity Daily[2]	Weekly[3]	Total sales	Total sales as a percent of weekly operating capacity
	5/1-5/3	8,953	15,220[4]	5,920	39
	5/4-5/10	9,086	46,339	14,574	31
	5/11-5/17	10,429	53,188	21,174	40
1	5/18-5/24	11,424	58,262	22,419	38
2	5/25-5/31	11,424	58,262	22,432	39
3	6/1-6/7	11,786	60,109	34,481	57
4	6/8-6/14	11,786	60,109	30,324	50
5	6/15-6/21	11,786	60,109	30,275	50
6	6/22-6/28	11,786	60,109	27,608	46
7	6/29-7/5	11,633	59,328	19,105	32
8	7/6-7/12	11,253	57,390	16,652	29
9	7/13-7/19	11,253	57,390	17,280	30
10	7/20-7/26	11,253	57,390	14,992	26
11	7/27-8/2	8,951	45,650	12,829	28
12	8/3-8/9	6,860	34,986	9,973	29
13	8/10-8/16	6,860	34,986	16,461	47
	8/17-8/23	5,140	26,214	8,708	33
	8/24-8/30	4,900	24,990	4,026	16
	8/31	4,900	4,165[5]	659	16
Total			874,196	329,892	38[6]

[1]These data are from a survey of ice plants conducted during the 1981 shrimp season, based on 24 ice plants. To convert to pounds or tons multiply these figures by 300 or 0.15, respectively.
[2]This column presents the sum of the rated capacities of the Louisiana ice plants on a daily basis, which may vary from week to week because some plants did not report sales for every week.
[3]Weekly operating capacity is defined as 85 percent of daily rated plant capacity operating 6 days per week.
[4]Based on 2 days of operation.
[5]Based on 1 day of operation.
[6]Mean value of total sales as a percent of weekly operating capacity.

Table 3.—Ice capacity and sales (in blocks of ice) for Mississippi and Alabama, 1981[1].

Week	Operating capacity Daily[2]	Weekly[3]	Total sales	Total sales as a percent of weekly operating capacity
6/1-6/7	7,035	35,879	24,547	68
6/8-6/14	7,035	35,879	31,380	87
6/15-6/21	7,035	35,879	30,131	84
6/22-6/28	7,035	35,879	24,734	69
6/29-7/5	6,692	34,129	19,348	57
7/6-7/12	6,555	33,431	19,351	58
7/13-7/19	6,555	33,431	17,830	53
7/20-7/26	6,555	33,431	14,925	45
7/27-8/2	6,349	32,380	14,823	46
8/3-8/9	6,502	33,160	13,404	40
8/10-8/16	6,555	33,431	14,626	44
8/17-8/23	6,555	33,431	13,246	40
8/24-8/30	6,555	33,431	10,694	32
8/31	—	—	326	—
Total		443,771	249,039	56[4]

[1]These data are from a survey of 18 ice plants conducted during the 1981 shrimp season. To convert to pounds or tons, multiply these figures by 300 or 0.15, respectively.
[2]This column presents the sum of the rated capacities of the ice plants on a daily basis, which may vary from week to week because some plants did not report sales for every week.
[3]Weekly operating capacity is defined as 85 percent of daily rated plant capacity operating 6 days per week.
[4]Mean value of total sales as a percent of weekly operating capacity.

Table 4.—Sales as a percent of weekly operating capacity (in blocks of ice) of Louisiana ice plants, 1980-81.

Week no.[1]	Percent utilization 1980	1981	Week no.	Percent utilization 1980	1981
1	59	38	8	37	29
2	56	39	9	34	30
3	52	57	10	35	26
4	46	50	11	37	28
5	44	50	12	37	29
6	39	46	13	45	47
7	37	32	Avg.	43	39

[1]These numbers refer to the week numbers in Tables 1 and 2 covering the period of time when the survey results were compared.

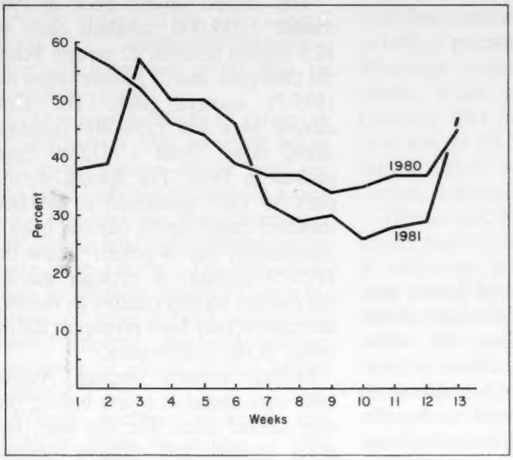

Figure 1.—Sales (blocks of ice) as a percent of weekly operating capacity of Louisiana ice plants, 1980-81.

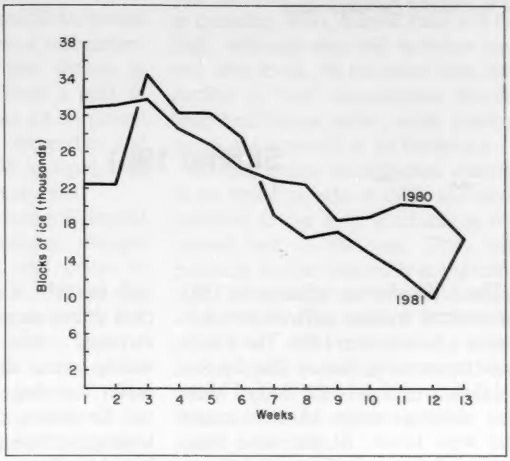

Figure 2.—Weekly sales of ice blocks by Louisiana plants, 1980-81.

ice sales range from 26 to 57 percent of operating capacity, with a mean value of 39 percent. This decline in the mean percentage for Louisiana is possibly due to the appearance of two new ice plants in 1981.

The comparison of the Louisiana ice plant survey for 1980 and 1981, of Tables 1-4, is presented graphically in Figures 1 and 2. The information presented in Figure 1 indicates the level of ice sales as a percentage of weekly operating capacity, and Figure 2 presents the absolute level of total sales of ice blocks for the 2 years of the survey.

Weekly data indicate that ice sales in 1981 did exceed the 1980 level, either as an absolute or as a percent of operating capacity, during the Texas closure (22 May-15 July or weeks 1-9 of Figures 1 and 2). However, as Figure 1 indicates, the level of sales did not approach operating capacity and, as the Texas closure came to an end, 1981 ice sales as a percent of operating capacity declined below the 1980 level. In Figure 2, the same pattern is observed for the absolute level of ice sales, with a decline of about 12 percent in total sales between 1980 and 1981 for the 13-week period. Thus, during the period of the Texas closure, demand for ice increased in Louisiana in 1981 relative to 1980.

As the Texas closure came to an end, ice demand declined below the 1980 level in both absolute and relative terms. This 2-year comparison of ice utilization in Louisiana implies a shift of fishing effort into Louisiana during the closure period and then out of Louisiana as the closure ended.

Acknowledgments

Without the persistent efforts of Kathleen Herbert (1980 Louisiana Survey), Doyal G. Van Orman (Mississippi and Alabama 1981 Surveys), and Samual J. Harden (Louisiana 1981 Survey), this research project and the resulting report could not have been prepared. We also extend our appreciation to the port agents in Louisiana, Mississippi, and Alabama for their help and assistance in carrying out the survey in 1980 and 1981.

Shrimp 1981

The U.S. shrimp industry in 1981 experienced another difficult year following a poor year in 1980. There were some encouraging factors like the record shrimp catches in the Gulf of Mexico[1], although prices of most count sizes were lower. At the same time, catches of shrimp in the south Atlantic and Pacific were off substantially. Fuel prices were about 20 percent above a year earlier, but they declined slightly in the second half of 1981 reflecting the weakness in the economies of many countries that has led to the temporary world glut of oil. Cold storage holdings of shrimp remained below 1980 levels in the first half of 1981, but holdings grew when Gulf catches increased sharply. Imports were virtually the same as in 1980.

Ex-vessel and wholesale prices dropped sharply in the summer, and firmed in the last 4 months of 1981. Consumption of shrimp was virtually unchanged from a year earlier. Demand recovered in the first half but slowed in the fourth quarter.

Total U.S. landings of shrimp in 1981 were 219 million pounds (heads-off), up 5 percent from a year earlier. Landings by region showed a marked change from the previous year. Catches in New England and the Gulf of Mexico were up substantially, but fell sharply in the south Atlantic and Pacific.

Shrimp landings in the Gulf states in 1981 hit a record 168.7 million pounds, up 29 percent from a year earlier and 1.4 million pounds above the previous high in 1977. Catches of brown and pink shrimp accounted for most of the increase, while landings of white shrimp were slightly above a year earlier. Landings in all Gulf states were up. Louisiana continued to be the leading producing state in the Gulf followed by Texas.

An important event in 1981 was the implementation of the Fishery Management Plan for the Gulf shrimp fishery. The major impact of the plan was to restrain all trawl fishing in the Fishery Conservation Zone (FCZ) from 9 miles out to 200 miles off the Texas coast for 45-60 days. The "Texas Closure" in 1981 was from 22 May to 15 July compared to the normal closure from 1 June to 15 July. Another measure prohibited trawl fishing in certain areas of the west coast of Florida between 1 January and 20 May to prevent gear conflicts between shrimp and stone crab fishermen.

Landings in the south Atlantic states fell by half to 10.4 million pounds in 1981 and were the lowest since 1963. Catches were off substantially in all states from North Carolina to the east coast of Florida.

Shrimp catches in the Pacific states totaled 38.5 million pounds in 1981, off 31 percent from 1980, and have trended downward since the record catch in 1977. The decline appears to have been caused more by resource conditions than by fishing pressure. That decline added to the problems the typically multi-species fishermen and processors of Pacific shrimp experienced in 1981. It was a difficult year, and resource conditions offer little hope of improvement in the near future, at least in the king crab, snow crab, and shrimp fisheries.

The canned shrimp pack in 1981 totaled 1,839,000 standard cases or 12.4 million pounds, 22 percent below the 1980 pack and 25 percent below the 1975-79 average pack. The Gulf canned pack was 1,070,000 standard cases, down from 1,753,000 cases packed in 1980. The Pacific shrimp pack in 1981 amounted to 769,000 standard cases, up 28 percent from a year earlier, but 24 percent below the 1975-79 average. A stronger market for canned shrimp relative to the frozen market may have prompted the increase in the Pacific pack.

Shrimp imports through August 1981 were ahead of a year before, but they slowed later. For the year, imports totaled 257 million pounds (heads-off), about the same as in 1980 and the 1975-79 average. Imports of raw headless shrimp were up 2 percent from 1980, primarily because of a one-third increase in shipments from Ecuador. Imports from the leading U.S. supplier, Mexico, fell by 14 percent. For raw peeled shrimp, imports declined 1 percent from a year earlier. Although the raw peeled total declined, shipments from India were resumed (after having been sharply curtailed in 1980 because of a Food and Drug Administration restriction on most imports from India, Taiwan and Hong Kong). Imports of canned shrimp increased 5 percent, and imports of other shrimp were down 10 percent from 1980. The most significant occurrence in imports was a quantum jump in imports of breaded shrimp from only 171,000 pounds in 1980 to 2,994,000 pounds in 1981. Most of the breaded shrimp imports originated in Mexico and represented over 95 percent of the total. The 1981 total surpassed the previous record of 1.3 million pounds imported in 1972.

Exports of domestic fresh and frozen shrimp in 1981 were 11 percent above 1980 and 38 percent below the 1975-79 average. The increase in 1981 was caused by the almost doubling of shipments to Mexico, compared with a sharp decline in 1980. Exports to Canada, the leading customer, declined 5 percent from 1980 to 7.6 million pounds.

[1]For a full analysis and discussion, see the eight articles in this special issue of the *Marine Fisheries Review*.

Exports of canned shrimp in 1981 declined 22 percent from a year earlier primarily because of the lower canned shrimp pack. Canada was the leading buyer with 80 percent of the total, or 3.6 million pounds.

Cold storage holdings of shrimp in the first half of 1981 remained below 1980 levels because of the weak demand and high cost of carrying inventories. However, the sharp increase in Gulf shrimp landings prompted an increase in inventories. The rate of increase in holdings slowed in late 1981 because of more normal catches and reduced imports. Year-end holdings were down 16 percent at 52.4 million pounds.

Annual average ex-vessel and wholesale prices of shrimp in 1981 were generally lower, but prices of larger sizes were higher. Prices for shrimp in the 26-50 count range were 3-8 percent lower than a year earlier. Prices of 15 and under, and 16-20 count shrimp were 15-20 percent above a year ago, while 51 and over count shrimp were about the same as in 1980. During July and August, when landings were very heavy, prices dropped sharply to a 3-year low. Prices strengthened in the latter part of 1981 but were still below the highs for the year. Prices continued to trend upward in early 1982.

Ex-vessel prices increased in the first quarter of 1981 and then dropped sharply. Prices of 31-40 count shrimp in the western Gulf peaked at $3.63/pound in March, slid to a low of $2.39 in August, and closed the year at $3.22/pound. Prices rose sharply in the first quarter of 1982 to $4.88/pound in April 1982, up 35 percent from a year earlier.

Wholesale prices followed the same pattern as ex-vessel prices but lagged about a month, and the swings were not as severe. Wholesale prices of 31-40 count shrimp at New York City reached $3.97/pound in May, fell to a low of $3.09 in August, increased to $4.00/pound in December, and hit a record $5.82 in April 1982.

Ex-vessel and wholesale prices for Pacific shrimp declined in 1981. Ex-vessel prices in Alaska averaged 27 cents a pound (heads-on) in 1981, off 8 percent from the previous year. Prices in all four states averaged $0.41/pound in 1981, 6 percent below a year earlier. Wholesale prices of tiny shrimp at Seattle, Wash., went from a peak in February 1981 of about $4.50/pound to a low of $3.20 in September and firmed slightly to $3.48 in April 1982 (frozen, 5-pound vacuum tins).

The demand for shrimp will depend on the state of the economy, changes in consumer income, and prices of meat and poultry. The demand for shrimp, believed moderate in the first half of 1982, was expected to improve in the second half. The second phase of President Reagan's tax cuts takes effect then, and this measure will increase consumer incomes. Exactly how much of the increase will be translated into spending as opposed to savings is in question. Also, interest rates will be high, although they will be below record 1981 levels. At the same time, the decline in beef consumption should keep beef prices stable, while poultry prices are expected to be moderate.

Shrimp prices strengthened sharply in the first 4 months of 1982, and were expected to rise more gradually in the second half of the year. They will probably decline seasonally in the summer, if landings are at near normal levels. The shrimp catch is difficult to predict at mid-year, but the Gulf shrimp catch is unlikely to exceed last year's record. The catch in the south Atlantic should improve after last year's poor catch.

Ten Appointed to Department of Commerce Marine Fisheries Advisory Committee

Commerce Secretary Malcolm Baldrige has announced ten appointments to the Department's Marine Fisheries Advisory Committee. The committee advises the Secretary on the living marine resource programs and activities conducted by the National Oceanic and Atmospheric Administration and its National Marine Fisheries Service.

Members come from every region of the country and represent commercial and recreational fishing interests, academic institutions, state marine resource agencies, consumer groups, and the environmental community.

The new appointees are: Robert D. Alverson, manager, Fishing Vessel Owners Association, Seattle, Wash.; Sen. H. Douglas Barclay, New York State Legislature, Syracuse, N.Y.; Glen Akens, Deputy Commissioner, Alaska Department of Environmental Conservation, Juneau, Alaska; Richard L. Leard, Executive Director, Bureau of Marine Resources, Long Beach, Miss.; Raymond J. Nesbit, board of directors, National Wildlife Federation, Sacramento, Calif.; Frank J. Barhanovich, owner, Latitude Gifts, Biloxi, Miss.; Gilbert C. Radonski, Executive Vice President, Sport Fishing Institute, Washington, D.C.; and Harry T. Kami, Chief, Division of Aquatic and Wildlife Resources, Agana, Guam.

George J. Easley, Administrator, Oregon Trawl Commission, Astoria, Oreg., has been reappointed for a second term.

Other members of the committee are: Alan J. Beardsley, Mark-It Foods, Kodiak, Alaska; Maumus F. Claverie, Jr., Attorney, New Orleans, La.; Joel Dirlam, professor of economics, University of Rhode Island, Kingston, R.I.; William C. Lunsford, Zapata Haynie Corp., Towson, Md.; Charlotte Newton, Virginia Citizens Consumer Council, Springfield, Va.; John P. Nickles, manager of state government relations, Pfizer, Inc., Atlanta, Ga.; Elizabeth Stromeyer, Secretary-Treasurer, Red Top Sporting Goods, Inc., Buzzards Bay, Mass.; Elizabeth L. Venrick, assistant research biologist, Scripps Institute of Oceanography, La Jolla, Calif.; Walter Walkinshaw, attorney, Seattle, Wash.; Ann McDuffie, food editor, *The Tampa Tribune,* Tampa, Fla.

Japan's 1981 Fishery Product Imports High

Japanese imports of fishery products in 1981 were the second highest on record both in quantity and value at 1,129,068 metric tons (t) with ¥879,881 million ($3,999 million), according to the customs clearance data released by the Finance Ministry (Table 1). The highest imports on record, 1,151,174 t with ¥930,738 million, occurred in 1979.

Frozen shrimp imports totaling 161,725 t worth $1,223 million, led all other products both in quantity and value, accounting for 14 percent in quantity and 31 percent in value of the total fishery imports. Imports in eight categories set a new record in 1981. These were shrimp, salmon, herring, salmon roe, octopus, sea bream, jack mackerel and live eel. Compared with 1980, significant gains in quantity were recorded in the imports of frozen jack mackerel (+331 percent), frozen albacore (+162 percent), frozen sea bream (+93 percent), frozen salmon (+81 percent), frozen herring (+66 percent), octopus (+58 percent), salted herring roe (+41 percent), and salted pollock roe (+36 percent), whereas sharp decline occurred in squid (−27 percent), whale meat (−25 percent) and smelt (−18 percent).

Table 1.—Japanese imports of fishery products, 1972-81

Year	Amount (t)	CIF value (10^6 ¥)	Year	Amount (t)	CIF value (10^6 ¥)
1972	480,649	190,338	1977	1,045,610	657,713
1973	658,425	300,074	1978	1,012,351	674,790
1974	604,141	323,239	1979	1,151,174	930,738
1975	710,414	385,529	1980	1,037,350	764,272
1976	814,516	563,468	1981	1,129,068	879,881

Top 10 fishery product imports (quantity)

Commodity	Metric tons	Commodity	Metric tons
Frozen shrimp	161,724	Frozen bigeye	42,757
Frozen octopus	100,400	Crab	31,039
Frozen salmon	70,341	Frozen yellowfin	29,557
Frozen squid	68,776	Frozen smelt	25,937
Frozen herring	50,117	Frozen jack mackerel	24,561

Top 10 fishery product imports (value)

Commodity	CIF value	Commodity	CIF value
Frozen shrimp	269,151	Salted salmon roe	30,507
Frozen salmon	74,161	Frozen bigeye tuna	27,583
Frozen squid	43,278	Live eel	25,960
Frozen octopus	39,871	Frozen yellowfin	17,276
Crab	33,075	Frozen herring	14,701

(Source: FFIR 82-7.)

Japan's 1981 Fisheries Catch Up 2% Over 1980

Japan's fisheries catch for 1981 totaled 11,336,000 t according to preliminary statistics released by the Japanese Ministry of Agriculture, Forestry, and Fisheries on 31 May 1982. Japan's 1981 catch was the largest in the world and represents a 2 percent increase over the 1980 catch of 11,122,000 t (Table 1).

Table 1.—Japan's fisheries catch, by major fisheries for 1977-81 and a comparison for 1980-81.

Fishery	Catch (× 1,000 t) 1977	1978	1979	1980	1981	Percent change[1]
Marine						
Distant-water	2,657	2,134	2,035	2,121	2,040	−3
Offshore	4,924	5,559	5,488	5,751	N.A.	N.A.
Coastal	2,107	1,990	1,953	2,037	N.A.	N.A.
Aquaculture	861	917	883	992	955	−4
Total	10,549	10,600	10,359	10,901	11,120	+2
Inland						
Aquaculture	82	90	95	94	92	−2
Other	126	138	136	128	124	−3
Total	208	228	231	221	216	−2
Grand total	10,757	10,828	10,590	11,122	11,336	+2
Whales taken (no.)	9,299	5,924	4,918	5,191	4,887	−6

[1]Percentage change from 1980 to 1981.
Source: U.S. Regional Fisheries Attache, U.S. Embassy, Tokyo.

The marine fisheries catch, representing 98 percent of the total, amounted to 11.1 million t, an increase of about 2 percent from 1980. The total increase in the marine fisheries catch was achieved despite decreases in the catch of distant-water fisheries and marine aquaculture. Offshore and coastal fisheries easily offset the losses in the other two sectors of marine fishing.

The decreasing distant-water catch reflects the continued effect of the establishment of 200-mile fishery zones in many countries, especially in those where catch quotas for Japanese fishermen have been imposed. However, the rate of decline in the distant-water catch, which was as high as 20 percent in 1978, decreased to only 3 percent in 1981.

Japan's inland fisheries catch, composing only 2 percent of the total, decreased by 2 percent. The harvest of whales declined by 6 percent in 1981, offsetting an increase in 1980. (Source: IFR-82/88.)

Ecuadorean Fisheries Research Progresses

The Ecuadorean Fisheries Institute (Instituto Nacional de Pesca or INP), is managing eight research projects ranging from biological studies of marine fish populations to the development of new fishery products as part of the government's 1980-84 fisheries development plan. The INP, through the South Pacific Permanent Commission, is also cooperating with Chile, Peru, and Colombia in several important marine research projects. These include an analysis of the El Niño phenomenon and a study, funded by the United Nations, on the environmental pollution in the Eastern Pacific.

Marine Species

The first three projects are biological studies of pelagic species: Mackerel, thread herring (pinchagua), and sardine. Three other INP projects deal with a variety of environmental and fishery subjects. The first of these is a marine geological study of coastal sediments, but this project is still in a preparatory stage. The INP hopes to get funding from the state oil monopoly (CEPE) for this project. CEPE is interested, but has made no definite commitment.

The second project is an aquaculture study focusing on the pond culture of marine shrimp, Ecuador's single most important fishery. Shrimp pond culture has grown spectacularly since 1975 and now produces over half of the $80 million worth of shrimp exported to the United States in 1981.

A third study will survey environmental pollution in the Gulf of Guayaquil. This area of mangrove estuaries is of crucial importance, both as a nursery ground for shrimp and as a source of newly discovered offshore natural gas. The INP Director, Roberto Jimenez, is particularly interested in this last project which will examine the tradeoffs between management of renewable natural resources and development of coastal oil and gas resources. The study will also suggest ways to harmonize the potentially conflicting uses.

Processing Technology

Under the INP processing technology project, a "pilot plant," in essence a small factory producing new or nontraditional fishery products, will be constructed. This project, of all the eight INP projects, has perhaps the greatest potential social impact. INP researchers are studying a wide variety of subjects including the use of solar fish dryers, the production of fish silage for use as a high protein animal feed, and the development of an inexpensive salted fish cake for human consumption.

Research on new methods of salting and smoking fish is particularly interesting to the INP since these techniques of preservation were in widespread use in the 1940's and 1950's, but lost favor with the advent of freezing technology. Much of the project will be carried out by extension workers in an effort to convince producers and low-income consumers to accept the appropriate technology and new products.

Freshwater Rivers

The last of the eight INP projects is called Proyecto Aguas Interiores (Inland Fisheries Project) and is concerned principally with water quality in rivers. The INP's research programs are widely diversified and offer numerous opportunities for scientific cooperation with United States research institutes, either directly or under various regional programs. Both INP Director Jimenez and his assistant, Lucia Solorzano, have studied in the United States and are extremely enthusiastic about their work. They have both expressed an interest in developing contacts with U.S. scientists and research institutes and have already established cooperative programs with other countries.

The INP has received at least two separate donations of scientific equipment from the Government of Japan. It has also used a vessel and scientific personnel under the United Kingdom's foreign aid program. The INP is now transforming its laboratory facilities in Guayaquil into what it believes will be one of the best fishery research laboratories in Latin America. (Source: IFR-82/64.)

Shrimp Bycatch Data Bank at Hull College

The Hull College of Higher Education in the United Kingdom (U.K.) is establishing a data bank on shrimp bycatch. Researchers from many different countries have been studying ways of utilizing the incidental finfish bycatch of the shrimp trawler fleet for years. The Center for Fisheries Studies at the college plans to develop a major international data base on this subject.

Center officials are currently researching the topic and contacting experts. The project will accumulate data on shrimp fisheries, the quantity and species composition of the finfish bycatch, and the potential and current utilization of the bycatch. The Center hopes eventually to produce global statistics on the bycatch.

The Center has already prepared a comprehensive listing of reference sources and some statistics, using both computer and manual searches, and hopes to make its reference lists and statistics available to other researchers by mid-1982. U.S. researchers interested in exchanging information can contact the Center by writing to: Pauline Godkin, Center for Fisheries Studies, Hull College of Higher Education, Queen's Gardens, Hull, North Humberside, England HU1 3DH.

EC "Guide Prices" Set to Protect Fishermen

The European Community (EC) Council has adopted regulations establishing 1982 guide prices for selected fishery products, intervention prices for fresh or chilled sardines and anchovies, and producer prices for tuna intended for canning. These new prices are part of an EC program to protect its fishermen from an unstable market for fishery commodities and competition from cheap foreign imports.

The program is based on guide

prices which are determined by averaging the EC wholesale prices of the produce during the last 3 years. This guide price is then used as a base price to determine other support prices such as reference, intervention, and producer prices. Reference prices are minimum import prices calculated as percentages of the guide price. When the import price of a product falls below the reference price, intervention measures are automatically triggered.

The EC regulations extend the 1981 guide prices for mackerel, anchovy and herring, and increase guide prices for other species from 2 to 6 percent. There were, however, some points of controversy among the EC member countries. Belgium, Ireland, and the United Kingdom indicated interest in protecting their domestic markets from cheap imported fish and consequently favored higher guide prices than those originally proposed by the Commission. The Federal Republic of Germany, Denmark, and the Netherlands were generally satisfied with the proposals. After considerable debate, the new proposals were adopted. (Source: IFR-82/15.)

West European, Canadian Fisheries Ministers Listed

The NMFS Division of Foreign Fisheries Analysis, which regularly monitors fishery developments throughout the world, has prepared the following list of West European and Canadian fisheries ministers and directors. Five independent fishery ministries exist in Denmark, France, Iceland, Ireland, and Norway. In Sweden, the National Board of Fisheries also functions independently. In the other European countries, the agencies responsible for fisheries are under different ministries, usually the Ministry of Agriculture where their titles range rom Minister of State and Under Secretary, to Director General. The fishery ministers and directors in Western Europe and Canada, as of April 1982, are listed below.

Belgium
Karel Michielson
Inspector in Chief—Director
Fishery Department
Ministry of Agriculture
Minister: Albert Lavens
Rue de Stassart 35
B-1050 Brussels, Belgium

Canada
Romeo LeBlanc
Minister of Fisheries
Department of Fisheries and Oceans
Ottawa, Ontario, Canada KIA OE6

Denmark
Karl Hjortnaes
Minister of Fisheries
Ministry of Agriculture and Fisheries
Borgergrade 16
1300 DK.K
Copenhagen, Denmark

European Economic Community
Giorgios Kontogeorgis
Fisheries Commissioner
Commission of the European Communities
Rue de la Loi, 200
1049 Brussels, Belgium

Faroe Islands[1]
Peter Reinurt
Fisheries Minister
Ministry of Foreign Affairs
Stormgade 10-12
DIC-1470 Copenhagen, Denmark

[1]The Faroe Islands are part of the Danish realm.

Finland
Heikki Suomus
Department of Fisheries and Game
Ministry of Agriculture and Forestry
Hallituskatu 3
00170 Helsinki 17, Finland

France
Louis Le Pensec
Ministre de la Mer
Ministere de la Mer
3 Place de Fontency
75007 Paris, France

Germany (FRG)
Gero Moecklinghoff
Ministerial Dirigent
Ministry for Food, Agriculture
and Forestry
Rochusstrasse 1
53 Bonn, FRG

Greece
Constine Simitis
Department of Agriculture and Fisheries
22 Menandrou Street
Athens, Greece

Iceland
Steingrimur Hermannson
Minister of Fisheries
Ministry of Fisheries
Lindarbae, Lindargata
Reykjavik, Iceland

Ireland
Patrick Power
Minister for Fisheries
22 Upper Merrion Street
Dublin 2, Ireland

Italy
Donato delli Bovi
Director General for Maritime Fishing
Viale Asia; 0144 Rome, Italy

Netherlands
J. de Koning
Ministry of Agriculture and Fisheries
P.O. 20401
2500 EK. The Hague, Netherlands

Norway
Hallstein Rasmussen
Director General of Norwegian Fishing
Ministry of Fisheries
Raadstuplass 10
Postboks 185-186
5001 Bergen, Norway

Portugal
Goncalves Viana
Secretary of State for Fisheries
Rua do Ouro 181-1; Lisbon, Portugal

Spain
Gonzalo Vazquez
Director General of Maritime Fisheries
Ruiz de Alarcon 1; Madrid, Spain

Sweden
Lennart Hennarz, Director General
National Board of Fisheries
Fack, 403 10; Gotenburg, Sweden

United Kingdom
W. E. Mason, Fisheries Undersecretary
Fisheries Department
Horseferry Road
London SW1P, 2AE: England, UK

Angling, Angling Records, and Game Fish Conservation

The 1982 edition of **"World Record Game Fishes,"** published by the International Game Fish Association, 3000 East Las Olas Boulevard, Fort Lauderdale, FL 33316, continues to grow as an important reference work for the serious angler-conservationist.

New articles in Section 2 of this edition include an excellent review of the threat to marine fishes from pollution caused by continued coastal development by Jack Pearce, Chief, Division of Environmental Assessment, NMFS Northeast Fisheries Center.

Problems with ciguatoxic fishes are also discussed in detail by Donald P. de Sylva and Mark Poli, of the University of Miami's Rosenstiel School of Marine and Atmospheric Science. They cover the occurrence of ciguatera, its symptoms and causes, affected fishes, which ones might be safe to eat, and how to minimize the chances of getting ciguatera.

And, DeWitt O. and Evelyn Myatt review the effects of midwater fish attractors established in a variety of settings around the world by state agencies, the NMFS, and by private companies. These devices, including midwater fish attractors, and trolling alleys, have had proven success in enhancing both recreational and commercial fisheries.

Advice for anglers on how to "pursue world records" is given by Steve Zuckerman, holder of 11 IGFA records, and Rick Gaffney, associate editor of *Hawaii Fishing News* tells how to rig lures like professional Hawaiian fishing guides. J. Leon Chandler describes the manufacture of braided lines and the reasons for their popularity.

Of course the volume is built around Section 4, the latest world sportfishing records (as of 1 January 1982) for over 140 species of freshwater, marine, and anadromous fish. This includes 97 pages of records in all-tackle, line class, and tippet class categories. These are accompanied by international angling regulations, world record requirements, and the IGFA's annual fishing contest rules and winners in Section 3.

Anglers will appreciate the inclusion this year of the descriptions and illustrations for more than 70 freshwater species in the "Guide to Fishes," Section 5. Data on saltwater species has also been revised and updated.

Section 1 provides data on the IGFA itself, its goals, services, etc. The book also includes a glossary of scientific and descriptive words and terms, and a multilingual list of the names of fishes. Specific data on the salmonid family and on the tunas is also included.

The appendices, another section themselves, list game fish records of other nations and continents, a directory of state fisheries agencies, a guide to game fish tag and release programs, and illustrated instructions for fishing knots. Finally, an index to common and scientific names of fishes is provided.

The volume has become the standard reference on gamefish angling records and provides much good, authoritative reading. Amply illustrated with excellent black and white and color photography, the 328-page paperbound book costs $6.95 postpaid ($8.75 outside the U.S.) and is available from the publisher.

Venoms and Venomous Species

"Venomous Animals and Their Toxins," by G. G. Habermehl, published by Springer-Verlag, Berlin, West Germany, and based on the translation of the second German edition of "Gift-Tiere und ihre Waffen," is intended to introduce biologists, chemists, physicians, etc., to the animal toxins. It provides a good review of the chemistry, toxic effects, and treatments of them. A significant portion of the handbook deals with toxins of marine species.

The author, president elect of the International Society of Toxinology, has done much chemical research on toxins, especially in elucidating the structure of the venoms. While directed at biologists and chemists, the volume would also be useful to and mostly understood by a more general audience. It provides useful insights into the modes of action and constituents of the different venoms. A short final section reviews the significance of the venoms for humans and therapeutic uses of several of the venoms.

A brief introduction reviews historical misconceptions about venomous animals and the generally low chances of being injured by one. Chapters 1 and 2 then review toxins associated with coelenterates (cnidarians and the venomous polyps, jellyfish, sea wasps, sea nettles, sea anemones, and corals) and mollusks (certain mussels, clams, snails, slugs, coneshells, and an Australian octopus).

Chapter 3 reviews toxins in arthropoda (arachnids, centipedes and millipedes, earwigs, beetles, moths, bees, wasps, and ants). Chapter 4 reviews the toxins of the echinodermata (sea cucumbers, sea urchins, starfishes, brittle and serpent stars). Chapter 5 reports data on poisonous fishes, mentioning ciguatera, tetrodotoxin, and fishes whose gonads or blood may be toxic. Numerous actively venomous fishes are also listed, along with the type of poisoning, treatment, and chemistry of the venoms where known. Chapters 6 and 7 are devoted

to the toxins of the amphibia and reptilia.

Each chapter suggests helpful references. The volume is indexed and also provides a list of institutes which provide antivenins. Paperbound, the small format (6×9″), 195-page volume is available from the publisher at DM34 (about $15.90, subject to change).

Fishing Vessel Stability

Publication of **"Stability and Trim of Fishing Vessels"** by J. Anthony Hind has been announced by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England. The author, a naval architect, has updated his 1967 edition, which was written primarily as a textbook. As such it gives a good basic knowledge of the subjects, through keeping explanations and mathematics relatively simple and clear.

Topics include first principles (i.e., tonnage, displacement, centers of gravity and buoyancy, equilibrium), initial or metacentric stability, inclining experiment, inertia and free surfaces, stability, trim, docking and grounding, dynamic stability and motion in a seaway, stability after damage. Pertinent formulae are given in Appendices. Indexed, the 132-page small format (5½×6¾″), hardbound volume is available from the publisher for £7.50 plus 75 p postage.

Canadian Pacific Herring

The Canadian Department of Fisheries and Oceans has published a 22-page booklet titled **"Herring on Canada's Pacific Coast."** The publication describes the life history of herring, pointing out that the center of abundance of this species in the eastern Pacific occurs in the waters off British Columbia. A history of the British Columbia herring fishery shows that the catch increased to a peak of 250,000 t in the late 1960's and then collapsed to a point where the fishery had to be closed to preserve the resource. Following the recovery of the stock, a lucrative roe fishery began in 1972, mostly for export to Japan. The pamphlet also describes the four current Canadian Pacific fisheries: The roe fishery, the spawn on kelp fishery, the herring bait fishery, and finally the fishery for herring used for human consumption. A short paragraph describes the management of the resource and the principles of stock identification, stock assessment, and "in season" management. This booklet is available from: Department of Fisheries and Oceans, Resource Services Branch, Pacific Biological Station, Nanaimo, B.C. V9R 5K6.

The Panamanian Fishing Industry

Panamanian fishermen reported landings of 193,000 t in 1980, a 35 percent increase over 143,000 t landed in 1979. The U.S. Embassy in Panama City has prepared a 24-page report describing the country's 1980 fishing industry. A copy of the report can be purchased for $5.00 by ordering report number ITA-82-01-012 from: National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

MTN Business Guide

A special Multilateral Trade Negotiation (MTN) business guide published by the International Trade Administration is now available from the Department of Commerce. This guide, on a country basis, reports on the eight MTN codes (Government procurement, product standards, industrial tariffs, customs valuation, import licensing procedures, trade in civil aircraft, subsidies/countervailing measures, and anti-dumping).

Extensive coverage is given to the government procurement code, including details on important government procurement entities, methods of bidding on contracts, and the need for local representation. Copies of "Business Guide to MTN: Results of the Tokyo Round of the Multilateral Trade Negotiations" (OBR 81=32), can be purchased from: U.S. Department of Commerce, Publications Distribution, Room 1617, Washington, DC 20230. The fee is $2.50, paid to the order of U.S. Department of Commerce/TOP.

Governing the Resources of the Puget Sound Region

Publication of **"Governing Puget Sound"** by Robert L. Bish, announced by the University of Washington Press, is the second book in a series on the region's marine resources, physical properties, and uses. Supported by NOAA's Office of Marine Pollution Assessment and Washington Sea Grant Program and the Environmental Protection Agency, the series continues to provide well written and authoritative documentation. This volume stands out with its clear, readable treatment of the legal and institutional framework encompassing Puget Sound resource decision-making processes.

The volume begins with a very brief review of the Sound, its resources, and the decision-making processes that impinge upon them, and then details the history of the constitutional web governing these processes and resource management decisions. The author further examines the exercise of Federal authority in commerce, navigation, fisheries, water quality management, etc. Much of this is relevant far beyond the region.

The role and interaction of Washington's State courts, agencies, and local governments are described. Indian reservations and tribal governments, shoreline management, regulatory systems are also reviewed and, finally, the author gives a short evaluation of the governance system. Indexed, the volume provides a bibliography and a list of legal cases cited.

The author, professor of Public Administration at the University of Victoria, British Columbia, and a research associate at the Institute for Public Policy Management at the University of Washington, Seattle, has provided an excellent and lucid account of the region's regulation, from the European historical and constitutional origins to present regulation. The volume, 137 pages, paperbound, small format (6×9″), is available from the University of Washington Press, Seattle, WA 98105 for $8.95.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Citations" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10- inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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